A LABORATORY COURSE IN GENERAL ZOÖLOGY

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A LABORATORY COURSE IN GENERAL ZOÖLOGY

A GUIDE TO THE DISSECTION AND COMPARATIVE STUDY OF ANIMALS

BY

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PREFACE

This book is a revised edition of the author's "Course in Invertebrate Zoölogy," to which have been added the two dissections, abbreviated and simplified, of the perch and the frog from his "Course in Vertebrate Zoölogy." The main purpose of this combination is to enable classes using the book to study representatives of vertebrates together with invertebrates, and thus to become acquainted with the structure of all the phyla of the animal kingdom.

In making this revision the author has not changed the character of the work or the order of the dissections; all those appearing in the "Invertebrate Zoölogy" are also given here. The plan of the course is to study each of the larger groups of the animal kingdom as a whole as far as possible, instead of detached types of the different groups taken more or less at random. The attention is directed constantly to the main structural features which characterize the entire group under consideration, and the study is thus made comparative.

In order that the systematic position of the animals examined and their larger affinities may be easily kept in mind, the names of the most important systematic groups to which the animal being studied belongs are placed at the head of each dissection, and a synopsis of the whole animal kingdom has been added in an appendix.

The course begins with arthropods, because the natural succession of forms in the animal kingdom, from the lowest to the highest, is more apparent in them than in any other group, except possibly in vertebrates, and it is easy for a beginner, by studying them, to learn the real significance of the blood relationship of animals. Whether, however, the student begins the course with insects or with crustaceans, and whether the first insect taken up is the wasp or the grasshopper, will be matters for the deci-

sion of the teacher. The course has been arranged so that any of these methods may be adopted.

Many teachers prefer to begin a laboratory course in general zoölogy with a frog or a fish, as convenient and relatively simple forms to use in introducing a class to laboratory methods of study, and this is one of the reasons for the expansion of this work by the introduction of these dissections into it.

While the comparative feature runs through the dissections in this course, each is complete in itself and does not depend upon any others. The teacher is thus enabled to give his class such dissections as he wishes and is not compelled to adopt the entire series to have his course complete. He can also reverse the order of the studies, if it suits his purpose better, beginning with the Protozoa and working upward to the higher groups.

An important feature of the plan of the course has been to give the student such practical directions that he can go on with his work intelligently and profitably without having an instructor constantly at his elbow. Far too much of the time of the average youthful student is often wasted in the laboratory because the instructor does not happen to be at hand at critical times to direct his work. The student will often do the work wrong in consequence, or perhaps he will not do anything at all; in either case his time is wasted and perhaps his material spoiled.

In most of the dissections the directions are so arranged that the student can complete the study with a single specimen, and in the longer dissections with two specimens, or at most three, and the order in which the different systems of organs are taken up in each dissection is made dependent upon this feature. The necessity of practicing economy of material is thus inculcated, and the habit is acquired of studying and handling each specimen with care and judgment.

H. S. PRATT

Haverford, Pennsylvania

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APPARATUS AND MATERIAL

The apparatus necessary for this course of study need not be extensive. Each student should be provided with the following instruments: either one medium-sized scalpel or two, a small one and one of medium or large size; two pairs of scissors, a large straight pair and a small pair, preferably with curved tips; either one pair of medium-sized forceps or two pairs, a small one and one of medium size, both straight and with corrugated tips; two dissecting needles, a probe, a blowpipe, a hand lens.

Each student should have a shallow dissecting pan, in the bottom of which is a layer of black wax; the depth of the pan should be about an inch and a half. If the lobster is dissected, however, a deeper pan without wax will also be needed. The student should also be provided with a number of pins which may be conveniently kept, while not in use, stuck in a large cork.

It is intended that most of the drawings of dissections should be outlines, usually more or less diagrammatic, made with a hard drawing pencil in a large blank book, the paper of which is good and firm, or upon sheets of drawing paper. The general use of colors by a class is not recommended, not because the use of them is not often helpful, but because in a class of young students it is difficult to prevent their abuse by many. The careless student will often be tempted to substitute the use of colors for careful drawing. Outline drawings of a dissection on a sufficiently large scale, and carefully made and labeled, will invariably be perfectly clear.

For the study of many of the animals or parts of them in this course, a compound microscope will be needed; a dissecting microscope will also be useful throughout the course, although not indispensable. The student should be provided with a number of glass slides and thick cover glasses. Water may be used as a medium for making temporary mounts of most of the objects examined under the microscope. A solution made of equal parts of water and glycerine, however, is usually preferable to water, as it will not dry up and,

besides, renders the object more transparent. None of the animals studied here need to be stained and mounted in balsam or other permanent medium. In the case, however, of the tapeworm, the hydroids, and perhaps one or two of the other forms, the animal can be studied with greater profit if thus stained and mounted, and it is recommended that the student be provided with such specimens.

As a rule the material needed can be easily obtained. Most of the animals studied as well as microscopic preparations may be purchased from the supply department of the Marine Biological Laboratory at Woods Hole, Massachusetts; General Biological Supply House, 761–763 East 69th Place, Chicago; New York Biological Supply Co., 34 Union Square, New York; Michigan Biological Co., 324 South State Street, Ann Arbor, Michigan; H. Edward Hubert, 3615 Melpomene Street, New Orleans; Southern Biological Supply Co., Natural History Building, New Orleans; Pacific Biological Laboratory, Pacific Grove, Washington; or other dealers in such supplies. Powers & Powers, Station A, Lincoln, Nebraska, will furnish live protozoans and hydras, also microscopic slides of these animals.

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GENERAL ZOÖLOGY

PHYLUM ARTHROPODA

CLASS: *Tracheata.* DIVISION: *Insecta.* ORDER: *Hymenoptera*

A WASP

Observe the size, shape, color, and external anatomy of the animal. The body is small in size; it is bilaterally symmetrical, that is, it has a right and a left side which are alike; it has a dorsal and a ventral side which are unlike, and also a forward and a hinder end which are unlike, the forward or anterior end being distinguished by the possession of important organs of special sense and the mouth. All of these features are characteristic of rapidly moving animals. Can you explain why? On the ventral side are the legs, which are also called appendages or extremities; on the dorsal side of the insect are the wings.

The external surface of the animal is very smooth. This feature is also correlated with rapid motion. Do you know how? The animal is encased in a hard shell, called the cuticula, which is composed largely of a very hard and resistant substance called chitin, and serves the double purpose of a protection for the internal soft parts and a surface for the attachment of muscles. It is, in fact, the skeleton of the animal and is called an exoskeleton, in contradistinction to an internal supporting structure, which would be called an endoskeleton. All invertebrate animals, except some of the lowest, are provided with a cuticular exoskeleton, but it is only the arthropods in which it is composed largely of chitin. In fact, the possession of such a hard and resistant external covering is one of the reasons why insects have so successfully maintained themselves in the universal struggle for existence.

Observe that the body of the animal is composed of a number of serially arranged segments. These are called somites, or metameres, and the segmented type of structure presented by the insect body is called a metameric type of structure. Observe that the body is sharply divided into three divisions — the **head**, **thorax**, and **abdomen**.

The **head** is unsegmented and bears on its anterior and dorsal surface a pair of long, jointed **feelers**, or **antennæ**, which are important sense organs, a pair of large **compound eyes**, and three small, dotlike eyes, called **ocelli**, which it may be necessary to look for with a hand lens; on its ventral side are the **mouth parts**, the organs which taste, grasp, and masticate the food. Examine these mouth parts carefully with a hand lens; notice that there is a short, overhanging **upper lip**, beneath which is a pair of powerful jaws having a lateral, or side, position instead of a dorsoventral one like the jaws of vertebrates. Beneath the jaws are two other pairs of mouth parts, the **maxillæ** and the **under lip**, which, however, will not be studied at present; notice the two pairs of elongated and segmented **palps**, which are probably organs of taste.

The **thorax** is composed of three somites, or metameres, which are called, respectively, the **prothorax**, the **mesothorax**, and the **metathorax**. Each somite bears a pair of legs on its ventral surface, and the mesothorax and metathorax bear each a pair of wings on the dorsal surface; thus the organs of locomotion of the animal are concentrated in the thorax. Find the sutures between the thoracic segments. The dorsal cuticula of each thoracic segment is called the **tergum**; the ventral cuticula, the **sternum**; and that of each lateral side, the **pleurum**. Thus we speak of the prosternum, the mesosternum, and the metasternum, etc.

In the **abdomen** the dorsal and the ventral portions of the cuticula are composed each of a distinct plate in each somite, which are called the **tergite** and the **sternite**, respectively. The abdomen bears no appendages; it contains most of the vegetative organs of the animal. At its hinder end are the **vent**, or **anus**, and, in the female, the **sting**. Look with the aid of a hand lens

for the **spiracles**, the external openings of the tracheal or respiratory system; they appear as a straight row of minute dots on each side of the abdomen and the thorax, one dot being on each segment on each side. In dark-colored wasps it may be impossible to see them with a hand lens. They are usually distinct in a caterpillar or a grasshopper, or may be seen in the wasp by removing a portion of the cuticula from the side of the body and examining the inner surface under the microscope.

Exercise 1. Draw an outline of the side view of the wasp on a scale of 4 or 5, indicating the segmentation and all the parts observed. The three thoracic segments may be difficult to distinguish at first, but if it is kept in mind that each one of them bears a pair of legs, the task will be easy. Number on your drawing the thoracic and abdominal segments, and carefully label all the different parts and organs.

Exercise 2. Draw an outline of the face on a scale of 10, showing exactly the relative length and the segmentation of the antennæ, the position of the compound eyes and ocelli and the upper lip, and label them all.

Exercise 3. Remove a metathoracic leg and draw an outline of it on a scale of 5. Its different segments, beginning with the proximal one, that is, the one nearest the body, are the following: the **coxa**, by which the leg articulates with the body; the **trochanter**, a very small segment; the **femur**, or thigh, a long segment; the **tibia**, or shank, also long; the **tarsus**, or foot, which is composed of five small segments, the last one of which bears the two claws. Label all of these.

Exercise 4. Remove a mesothoracic wing, extend it, and draw a picture of it on a scale of 5, indicating its venation.

CLASS: *Tracheata*. DIVISION: *Insecta*. ORDER: *Coleoptera*

A LARGE BEETLE

Compare the animal with the wasp. We notice in the first place the heavier and clumsier body and the smaller head. The animal is evidently much less active and also less intelligent than the wasp. We notice also that the wings lie close to the body instead of being raised above it. The forward, or mesothoracic, wings are hard and thick; they are not used for flight, but cover the metathoracic pair and the hinder part of the body and thus form an additional protection to the back. They are called the **wing-covers**, or **elytra**. The entire body of most beetles, in fact, has a thicker cuticula and, consequently, a more effective external covering than that of the wasp. This feature may be correlated with the smaller intelligence of the animal. Opening the elytra, we notice beneath them the membranous metathoracic wings with which the animal flies; we notice also that they are folded transversely as well as longitudinally. These wings are wanting in some of the running beetles, where the wing-covers are sometimes fused. Note the **scutellum**, the small triangular plate between the base of the wing-covers. Find the **eyes** and note their small size. Are **ocelli** present? Find the **antennæ**; in some beetles they are often concealed beneath the sides of the head.

Exercise 1. Draw an outline of the dorsal aspect of the beetle on a scale of 4 or 5. First, however, spread and pin the right wing-cover and wing. Number the thoracic and abdominal segments and label all the parts observed.

Exercise 2. Draw an outline on the same scale of the ventral aspect of the beetle, tracing carefully the sutures between the segments. Number the thoracic and abdominal segments.

Exercise 3. Remove a mesothoracic leg and draw an outline of it on the scale of 5. Label the segments.

Exercise 4. Remove a wing and draw an outline of it on a scale of 5, tracing in the veins.

CLASS: *Tracheata*. DIVISION: *Insecta*. ORDER: *Diptera*

A FLY

Kill several bluebottle flies or large house flies, without mutilating them, and impale one specimen on a slender insect pin or a needle. Stick the pin or needle into a cork or a small piece of wood, in order to be able to handle it easily, and study the external anatomy of the fly with the aid of a hand lens.

Observe the compact body of the animal, and note that it is distinctly divided, like that of the wasp, into three divisions: the **head**, the **thorax**, and the **abdomen**. Observe the color and the hairy surface of the body, including the legs and the wings. These numerous **hairs** are projections of the cuticula, and perform a useful function as tactile organs; that is, they are sensitive to vibrations of the atmosphere, and thus function as sense organs in that they aid in giving the animal a knowledge of its surroundings. Note the three pairs of long, strong **legs** and the single pair of **wings**. The fly has unusual locomotory powers. Correlated with these powers are the long cuticular hairs just mentioned, and also the very large composite **eyes**. An active, rapidly moving animal like the fly needs well-developed organs of orientation. The eyes are larger in the male than in the female, and are closer together on the top of the head. The two sexes may thus be distinguished.

Between the large eyes are the three minute accessory eyes, or **ocelli**. Note the peculiar form of the small **antennæ**, with their pinnate terminal portion. Extend the **proboscis** and observe its complex structure and the **oral lobes** at the lower end. The fly eats only fluid food, which it sucks up through its proboscis.

The **thorax** is of relatively large size, being almost entirely filled with the very extensive musculature of the legs and wings. The three thoracic somites are of unequal size. The middle one is the largest and bears the wings. Note that the hinder margin of the basal portion of the wing is divided into three prominent lobes. The posterior thoracic somite is the smallest and bears the **balancers**, which are the morphological equivalents of the second

pair of wings, possessed by most insects. These are a pair of minute, white, knobbed organs, which project backward from the posterior wall of the somite, each one being covered by the basal lobe of the wing on that side. They have a sensory function.

The **abdomen** is composed of eight somites in the male fly and nine in the female. Of these, however, four somites are much larger than the others and make up the greater part of the abdomen. The sixth, seventh, and eighth in the male are very small and rudimentary. In the female the posterior four form a long, tubular **ovipositor**, which is usually telescoped into the abdomen but can often be squeezed out by a little pressure. Each of the five anterior abdominal somites has a pair of **spiracles**. Find them.

Exercise 1. Draw an outline of the dorsal aspect of the fly on a scale of about 10, indicating the segmentation and the parts observed, including the venation of the wings. Label all the parts observed.

Exercise 2. Turn the fly over on its back and draw one of its legs on a large scale. The names of the different segments of the leg may be obtained from Exercise 3 on page 3. Note, between the two claws on each foot, the two **pulvilli** — the hairy adhesive pads by means of whose sticky secretions the fly can walk on an inverted surface.

Exercise 3. Draw on a large scale a side view of the head with the proboscis extended. Note carefully the form of the antennæ and of the proboscis. The latter is homologous to the under lip, or labium, of other insects.

CLASS: *Tracheata.* DIVISION: *Insecta.* ORDER: *Orthoptera*

A LARGE GRASSHOPPER

Observe the shape, color, and external anatomy of the animal. Note the long, vermiform body and the large head. The body, as in all insects, is made up of a number of serially arranged segments, called **somites**, or **metameres**, which fall into two divisions, the thorax and the abdomen. The **head** is unsegmented, being composed of a number of completely fused somites, and bears upon its dorsal and anterior surface a pair of long, jointed feelers, or **antennæ**, which are important sense organs, a pair of large compound **eyes**, and three small, dotlike eyes, called **ocelli**, which it may be necessary to look for with a hand lens; on its ventral side are the **mouth parts**, the organs with which it tastes, grasps, and masticates its food. Examine these mouth parts with a hand lens. Observe the long, broad **upper lip** and pass a needle under its ventral edge. Back of the upper lip will be seen the strong **mandibles**, and by pressing these to the right and left the two remaining pairs of mouth parts, the **maxillæ** and the **under lip**, will be seen. Note the two pairs of jointed **palps** belonging to them, which are probably organs of taste. These parts will all be studied later in detail.

The **thorax** is made up of three somites, which are called the **prothorax**, the **mesothorax**, and the **metathorax**. Notice that the thorax is not separated from the abdomen by a constriction, as it is in the wasp, but that it may be easily distinguished from the abdomen by its greater diameter. The prothorax is movable, as in the beetle, and its dorsal and lateral surfaces are covered by a large shield. On the ventral side of the prothorax, between the prothoracic legs, is, in many grasshoppers, a short projection. The mesothorax and metathorax are united immovably with the abdomen and are covered by the two pairs of wings. The anterior, or mesothoracic, wings are parchment-like and are not functional in flying, but, like the wing-covers of beetles, are held out at right angles to the body during flight. The metathoracic wings are membranous and when at rest are folded longitudinally like a fan

beneath the forward wings. Each somite bears a pair of legs on its ventral surface. The cuticula of each thoracic somite is composed of a number of distinct plates.

The **abdomen** is made up of eleven somites, which, however, are not all perfect segments, the ventral portion of several of the terminal somites being wanting. The posterior end of the abdomen is different in the two sexes, the female possessing an ovipositor, by means of which she buries her eggs in the ground. The ventral portions of the ninth, tenth, and eleventh somites are wanting in the female, the last complete somite being the eighth. The dorsal portions of the three terminal somites, however, are present. Projecting from the hinder end of the abdomen is the **ovipositor**, which consists of two pairs of short, movable, curved, and pointed structures. One of these pairs is dorsal in position, and the **anus** is at its base; the other is ventral, and at its base is the external opening of the **oviduct**. Extending from the posterior border of the tenth somite is another pair of pointed projections, called **cerci**, which may have a sensory function. Just beneath each cercus is a plate called a **podical plate**, which forms the hinder end of the body. Between the two podical plates on the dorsal side of the animal is the small, triangular eleventh somite.

In the male an additional ventral plate, called the **genital plate**, forms the hinder end of the body; the **podical plates** and the **cerci** are large. The eleventh somite is a small, triangular plate, dorsally situated, beneath which is the **anus**.

On the lateral side of the first abdominal segment note the **auditory organ**, a large, circular opening covered by a membrane. With the aid of a hand lens find the **spiracles** of the thorax and the abdomen. Ten pairs are present, one pair on the anterior margin of both the mesothoracic and the metathoracic segments, and one pair on each of the eight anterior abdominal segments, that on the first abdominal segment being just within the margin of the auditory organ.

Exercise 1. Spread out and pin down all four wings and draw an outline of the dorsal aspect of the grasshopper on a scale of 2 to 4. Number the thoracic and the abdominal segments and label all the parts observed.

Exercise 2. Cut off the wings from the left side of the body and draw an outline of the side view of the thorax and the two anterior abdominal segments on a scale of 5 or 6. Note that both the mesothorax and the metathorax are divided by a diagonal suture into two portions. Number the segments and label all the parts.

Exercise 3. Draw a side view of the posterior end of your specimen (whether male or female) on a scale of 5 or 6, showing accurately the arrangement of all the parts, and label them all.

Exercise 4. Draw an outline of the ventral surface of the thorax on a scale of 5 or 6. Note the dovetailing of the anterior margin of the metathorax with the posterior margin of the mesothorax and that of the first abdominal somite with the metathorax; note also the attachment of the legs.

Exercise 5. Remove a metathoracic leg and draw an outline of it on a scale of 3. The segment by which it articulates with the body is the **coxa**; the next segment is the **trochanter**, which in the grasshopper, however, is not a free segment, but is fused with the following one, the **femur**; the latter is the largest segment of the leg and has V-shaped muscle impressions on its surface; the next segment is the **tibia**, or shank; the end segment is the **tarsus**, or foot, which is made up of five smaller segments; the terminal one of these bears two claws, between which is a structure called the **pulvillus**. This organ is an adhesive pad which enables the animal to walk and spring on smooth surfaces. Label all of these parts.

Exercise 6. Draw an outline of the face on a scale of 5 or 6. The large plate which forms the top, front, and sides of the head, in which the eyes, ocelli, and antennæ are situated, is called the **epicranium.** The sides of the epicranium, back of the eyes, are the **genæ**, the top is the **vertex**, and that part which forms the anterior surface is the **front.** Ventral to the epicranium is a broad, short, median plate called the **clypeus**, beneath which is the **upper lip.** The antennæ are the first pair of appendages. Label all parts.

The Mouth Parts. These consist of the median upper lip, or **labrum**, the paired **mandibles**, the paired **maxillæ**, the median **hypopharynx**, and the paired under lip, or **labium.** The paired mouth parts are the second, third, and fourth pairs of appendages, the antennæ being the first pair.

Exercise 7. Remove the labrum with scissors and draw it on a scale of 5.

Exercise 8. With strong forceps remove the dark-colored mandibles and draw the inner surface of one of them on a scale of 5.

Exercise 9. Remove the maxillæ, which lie just back of the mandibles, being careful to take out the entire structure. Mount them on a glass slide in water with the posterior side uppermost, and examine them under the microscope. Note the following parts: the basal segment, or **cardo**, by which the maxilla articulates with the head; the **stipes**, the broadest segment of the structure; the **inner** and the **outer lobes**, which project from the distal edge of the stipes; and the **maxillary palp**, which projects from the lateral edge of the stipes. Draw a maxilla on a scale of 5 and label all of these parts.

Exercise 10. Note between the maxillæ and just in front of the labium a small median projection, the hypopharynx. Remove the labium, taking care to leave none of it in the animal, and mount it on a slide. Note the basal segment, by means of which the labium articulates with the head, and the two jointed **labial palps**, which project from the lateral edges. The labium is a second pair of maxillæ fused in the median line. Trace the homologies between the parts of the labium and those of the maxillæ. Draw the labium on a scale of 5 and label its parts.

Internal Anatomy. Take the grasshopper in the hand and with a pair of fine, sharp scissors cut a slit through the body wall a little to one side of the mid-dorsal line from one end of the body to the other, using great care not to injure the organs within. Place the animal, dorsal side up, in a shallow pan with a wax-covered bottom containing water. First, with two strong pins, pin the head to the wax and then the extreme hinder end of the body; then carefully spread the cut edges of the body wall as widely as possible to the right and left and pin them down, using many pins on each side. Observe the organs as they lie in the body cavity. In the thorax will be seen the strong locomotory muscles. Lying immediately beneath the dorsal abdominal wall in the median line is the **heart**; this may have been destroyed by the incision, but if not, it may be recognized as a narrow, transparent tube of the diameter of a needle, flanked by paired triangular muscles which hold it to the body wall. Immediately beneath the heart is a loose network of yellowish, fatty tissue,

called the **fat body**, which covers the viscera. Remove this carefully. The **alimentary canal** will be disclosed, a large tube running through the median axis of the body; above its abdominal portion are the paired **reproductive glands**, from which a **duct** passes on each side around the alimentary canal to the ventral side of the animal. Notice the silvery air tubes, or **tracheæ**, on each side of the alimentary canal; also observe the tangled mass of delicate brown threads, the urinary, or **Malpighian, tubules**, between the reproductive glands and the alimentary canal.

Exercise 11. Make a sketch of the animal on a scale of 5, showing the internal organs, and label them all.

The Digestive System. With fine scissors sever the alimentary canal at its extreme posterior end, where it joins the anus. With great care draw it forward between the ducts of the reproductive organs and from beneath those organs, loosening it from the surrounding tissues with a needle. Identify the following divisions of the alimentary canal: (1) the **pharynx**, the space just back of the mouth; (2) the **œsophagus**, the narrow tube which runs upward from the pharynx and, bending back, enters the thorax, where it enlarges to form a pouch called the **crop**; (3) the **salivary glands**, a pair of delicate, branched organs, one on each side of the crop, the **ducts** of which run forward to the pharynx; (4) the **gastric cæca**, eight elongated sacs which encircle the base of the crop; (5) the **stomach**, a large tube which extends back to the point where the delicate urinary, or Malpighian, tubules join the alimentary canal; (6) the **intestine**, the hinder portion of the alimentary canal, which ends at the **anus** and is made up of three divisions.

The Excretory System. The kidney of the insect consists of the **Malpighian tubules**. These are delicate, tubular glands, about fifty in number in the grasshopper, which unite with the alimentary canal and discharge their products into it at the point of juncture of the stomach and the intestine. They extend freely into the body cavity and excrete urinary wastes from the blood, in which they lie immersed.

Exercise 12. Make a drawing of the alimentary canal and the Malpighian tubules on a scale of 7 and label all of the parts.

The Reproductive System: the Female Organs. The two **ovaries** are closely bound together by a web of connective tissue and tracheæ so as to form a single mass, which lies above the intestine. If your specimen is a female, part this mass along the median line and with a needle gently remove some of the connective tissue surrounding it. Examine it with a hand lens; each side is a separate ovary and will be seen to be a collection of parallel, tapering tubules, their smaller ends being in the median line, their longer ends projecting back to the tubelike oviduct. These tubules are called **ovarioles**; it is in them that the eggs develop. How many tubules do you count on each side? Notice the elongated eggs in each ovariole. How many do you see in each one? The two **oviducts** proceed from the ovaries to the ventral side of the animal, where they unite to form a median tube, the **vagina**, which opens to the outside between the **ovipositors**. Just above the vagina is a small sac, the **receptaculum seminis**, which is connected by a long, sinuous duct with the exterior. The sac becomes filled with spermatozoa during pairing, which fertilize the eggs as they pass out of the vagina.

The Male Organs. The paired **testes** which secrete the spermatozoa lie above the intestine, bound together by connective tissue and fat. Each testis consists of a bundle of elongated tubes, with which a duct called the **sperm duct** connects posteriorly. The two sperm ducts run, one on each side of the intestine, to the ventral side of the animal, where they meet to form a median tube, which leads to the genital pore just beneath the anus.

Exercise 13. Make a semidiagrammatic drawing representing all the parts of the reproductive tract of your specimen.

The Respiratory System. The **spiracles** have already been noted. They are the external openings of the **tracheæ**, a system of fine air tubes which extend throughout the entire body of the insect and through which fresh air is introduced into every part of it. The blood is thus constantly aërated, and there is never any venous blood present. This arrangement results in a very active metabolism and is one of the causes of the extraordinary amount of energy which characterizes most insects. With the

aid of a hand lens examine the tracheæ in different parts of the body. They may be easily detected by their silvery gleam. Notice the arrangement of the main **tracheal trunks**, including those which connect with the spiracles, also the arrangement of the **air sacs**, which are expansions of tracheæ. Mount a small portion of the fatty tissue containing tracheæ in water or glycerine and examine them with a compound microscope. Notice the **spiral threads** which line the tracheæ. Find the connections of the tracheæ with the spiracles.

Exercise 14. Make a drawing of a trachea seen under a high power of the microscope.

The Circulatory System. This system is very simple in insects, being correlated with the great complexity of the respiratory system. Instead of the blood being carried to the respiratory organs to be aërated, as is the case in vertebrates, rendering necessary a complicated system of blood tubes connecting the remotest parts of the body with the respiratory organs, the respiratory organs are themselves a system of tubes which introduce air to every part of the body. The insect has a blood fluid which lies in the body cavity. The only circulatory vessel present is the tubular **heart.** This organ, whose position has already been noted, has a closed hinder end and segmental **valvular openings** along its sides. By its contractions the blood is sent into the forward portions of the body, whence it flows back into the hinder portions and enters the heart again through the valvular openings. To observe the heart of an insect is not always easy, because of its position so near the dorsal body wall and its great delicacy of structure. An easy method is to mount a live, transparent, aquatic insect larva, such as that of the mosquito, on a slide in water and observe it under a compound microscope. The heart and its action may be easily studied.

The Nervous System. Cut off the alimentary tract at its forward end, taking care not to injure the two nerve connectives which pass to the brain, and remove all the viscera from the body. The **nerve cord** will be seen lying on the ventral body wall of the abdomen, in the median line, often concealed by fat. It will be

seen to be double and to contain, in the abdomen, five enlargements, the **ganglia**, from each of which fine **nerves** radiate. Trace the nerve cord from the abdomen into the thorax. It is here protected by hard projections of the body wall, which must be carefully removed. Four large ganglia will be found here, the three posterior ones of which are the **thoracic ganglia**. The one in the forward portion of the prothorax really belongs to the head and is called the **subœsophageal ganglion**. From it a pair of nerve connectives passes to the dorsally situated **supraœsophageal ganglion**, or **brain**. The brain is the largest ganglionic mass in the body and is situated in the top of the head between the eyes. Lay bare the brain. Notice the **optic lobes** going to the eyes, and between them the much smaller **ocellar lobes** sending nerves to the lateral ocelli. Beneath the optic lobes are the **antennal lobes**, which send nerves to the antennæ; near them in the median line is the **median ocellar lobe**, which sends a nerve to the median ocellus.

Exercise 15. Make a large sketch of the nervous system as far as observed, representing it in an outline of the animal's body, and show in which segments the different ganglia occur.

Exercise 16. Draw a diagram representing a side view of a grasshopper on a scale of 3 or 4, in which the segmentation, the relative position of the heart, the alimentary tract, and the nervous system are accurately indicated.

CLASS: *Tracheata.* DIVISION: *Insecta.* ORDER: *Lepidoptera*

AN INSECT LARVA: A CATERPILLAR

Notice that the head, thorax, and abdomen are not set off from one another. The body is thus wormlike in form, there being almost no specialization of the body parts. Determine how much of the body is thorax and how much abdomen. The thorax bears three pairs of jointed legs, each one terminating in a single hook. The abdomen also bears several pairs of legs, which are not like those of the thorax. How many are there and in what do they differ from the thoracic legs? Find and count the spiracles, which are usually easily seen.

Exercise 1. Draw an outline representing a side view of the animal on a scale of from 2 to 6; number the thoracic and abdominal segments, show the spiracles, and label all the parts.

Study the **head** with the aid of a hand lens. Notice the pair of large, convex plates which, with the small, median, triangular plate, form the wall of the head. Near the lower edge of each of the convex plates are several minute **ocelli**; count them. On the ventral side of the head find the **antennæ**; how many joints are there in each? The mouth parts are between the antennæ. The **labrum** is bilobed, and beneath it are the dark-colored **mandibles.** Just back of these are the **maxillæ** and the **labium**, the latter being a median, elongated, conical organ between the maxillæ. The external opening of the silk glands is in the labium.

Exercise 2. Draw a front view of the head on a scale of 7.

Internal Anatomy. With fine scissors make a longitudinal incision the length of the animal in the dorsal integument, a short distance to one side of the median line. Turn the integument to the right and left and pin it down. If it has not been destroyed, observe the **heart.** It is a straight, transparent tube lying in the mid-dorsal line just beneath the integument. Note the large, tubular **alimentary tract** surrounded by delicate, glistening tracheæ and by the white and often filamentous fat. Its forward

portion is the **œsophagus**; the middle and largest portion is the **stomach**; the narrow portion back of the stomach is the **intestine**, which communicates with the anus. In the forward portion of the body cavity, along the wall of the œsophagus, is a pair of delicate, tubular **salivary glands** which extend forward and communicate with the mouth. Note and trace the course of the much larger, tubular **silk glands** on the ventral body wall; they are also a single pair and communicate with an opening in the labium.

Find and carefully trace the course of the six **Malpighian tubes**, which lie along the stomach and join it at its posterior end.

Exercise 3. Draw an outline of the opened animal on a scale of 6, showing the organs above described as far as they have been observed. Represent the segmentation and show accurately the position of the organs in their proper segments.

Sever the œsophagus and remove the stomach and the intestine from the body. Study the nervous system. Note the arrangement of the tracheæ with reference to the spiracles. Note the longitudinal muscle bands which form a part of the body wall; note also their segmental arrangement.

Exercise 4. Draw an outline of the opened body on a scale of 6, showing and numbering the segments. Draw in it the nervous system, representing accurately the number of ganglia and placing them in the proper segments, together with the tracheæ and muscles.

The **reproductive system** consists of two small sexual glands and a duct leading from each. There is no external pore.

CLASS: *Tracheata*. DIVISION: *Myriapoda*

A CENTIPED (*LITHOBIUS*)

Myriapods are wormlike animals which live under logs and stones, beneath the bark of decaying stumps and trees, and in other dark, damp places. The two main groups of myriapods may be easily recognized by the differences in shape and habits, — the centipeds (Chilopoda) being flattened and very active animals with one pair of legs to a segment, the millipeds (Diplopoda) being usually cylindrical animals with short legs, two pairs of which are present on most of the segments.

Observe the vermiform body, the well-marked segmentation, and the segmented legs; note also the lack of specialization among the segments, there being no division into thorax and abdomen. The animal is plainly an arthropod, but it is not an insect; it is a lower animal than an insect, because its body shows less specialization. Note the single pair of **antennæ** and the insect-like **mouth parts**, which consist of a pair of **mandibles** and two pairs of **maxillæ**; also the large **hooklike appendages** just back of the head. These latter are homologous to the first pair of legs; they are the principal organs of prehension and are provided with poison glands which open on the inner surface near the end. Note the **anal feelers**; these are homologous to the hindermost legs and enable the animal to perceive what is back of it.

Exercise 1. Draw an outline of the dorsal aspect of the animal on a scale of 5 and label all the organs observed.

Exercise 2. Draw a ventral view of the head on a scale of 10, showing the cephalic appendages in position.

Exercise 3. Remove, under a dissecting microscope, the prehensile hooks and the mouth parts, beginning with the posterior ones and working forward, and the antennæ. Mount them on a slide and draw an outline of each. Compare the different structures of the mouth parts with those of the insect and label them all.

The Internal Organs. The digestive, circulatory, respiratory, excretory, and nervous systems are similar to the same systems in insects. They will not be studied in this dissection.

CLASS: *Arachnoidea*. DIVISION: *Arachnida*

A SPIDER

As large a spider as possible should be obtained for this study. If a small one is used, it is usually well to stick a slender insect pin through it, in order to be able to handle it easily, and it should be studied with the aid of a hand lens. Observe the form and color of the animal. The body is unsegmented (although the body of the embryo spider is distinctly segmented) and is made up of two parts, the **cephalothorax** and the **abdomen.** What does the embryonic segmentation indicate as to the ultimate relationships of spiders? Observe the **hairs** which cover the body and legs. They are projections of the cuticula and are important sense organs, being sensitive to vibrations of the atmosphere. They thus aid in giving the animal information as to what is going on about it.

The Cephalothorax. This division of the body is equivalent to the head and thorax of insects. Observe carefully the eight eyes at or near its forward end, both the size and the arrangement of which vary much in the various species of spiders. The ventral surface bears the six pairs of appendages, the **mandibles**, the **pedipalps**, and the four pairs of **legs.**

The **mandibles**, the anterior pair, occupy a vertical position at the front end of the body and consist each of a basal portion and a terminal claw, near the tip of which is the pore from which poison is injected into the bite. In consequence of the vertical position of its mandibles the spider can strike only an insect which is beneath it.

The second pair of appendages are the **pedipalps.** These are leglike and contain one less segment than the legs. The basal segment of the pedipalp is called the **maxilla.** The two maxillæ are flattened structures situated on the underside of the cephalothorax just back of the mandibles, their forward, medial margins, which cover the mouth, being used to lacerate and squeeze the food so that the animal juices can be sucked up. Spiders prey exclusively upon living animals, but they can take in only liquid food. The pedipalps of the female spider differ in shape from

those of the male, and the two sexes may be distinguished in this way. In the female the pedipalp looks exactly like a small leg; in the male the terminal portion is expanded and very complex in structure, being used by the animal in the act of pairing.

The third, fourth, fifth, and sixth pairs of appendages are the **legs**; they are used by the spider for a variety of purposes besides walking. They are important as tactile organs, their great length increasing their usefulness in this respect, and they undoubtedly compensate the animal in a certain degree for the lack of antennæ. The legs are also of use in spinning and manipulating the web, the complex structure of the claws being associated with this function.

The median plate between the maxillæ on the ventral side of the body is the **labium**; the one between the bases of the legs is the **sternum.**

The Abdomen. The dorsal surface is usually marked by several pairs of depressions, which mark the points of attachment of muscles. At the hinder end, on the ventral surface, are three pairs of **spinnerets.** Study these carefully with the aid of a hand lens. At the end of each spinneret are numerous microscopic holes, from which is exuded the semifluid silk. This is made up of many soft strands, which harden as they unite to form the thread.

A study of the embryology of the spider shows that the spinnerets are homologous to abdominal legs.

Note the **spiracles**, the external openings of the respiratory organs, the tracheæ and the lungs. A short distance in front of the spinnerets in the ventral surface of the abdomen is the single, median, minute **tracheal spiracle**, which it is often difficult to see. The **lung spiracles** are a pair of large slits near the anterior end of the abdomen, each one at the lateral end of a transverse fold of the integument. Between them in the median line is the **genital pore.** In the female spider it is covered by a large and complex plate called the **epigynum.**

Exercise 1. Cut off the legs on the right side of the body and draw an outline of a side view of the spider on a scale of from 5 to 10, putting in only the basal portion of the legs but all the pedipalps and the mandibles. Carefully label all the parts observed.

Exercise 2. Draw an outline of the ventral aspect of the body on the same scale, putting in and labeling all the parts observed.

Exercise 3. Draw the front end of the body on a scale of 10, showing the mandibles and the eight eyes.

Exercise 4. Draw the pedipalp on a scale of 6.

Exercise 5. Draw one of the legs on a scale of 6.

Exercise 6. Cut off the terminal joint of one of the fourth pair of legs and study it under a compound microscope, noting the shape of the claws and the hairs which often surround them. Draw them.

The **internal anatomy** of the spider will not be studied in this dissection.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Decapoda*

A CRAYFISH OR A LOBSTER

These two animals are very common, the one in fresh and the other in salt water. In external form and internal anatomy they are exceedingly similar to each other, and the same directions for dissection may be made to apply to either. In habits and general method of life the animals also resemble each other; they move about at or near the bottom of the water, preferring regions which are rocky or stony, and feed upon small animals of all kinds and upon carrion.

Observe the shape, color, and external anatomy of the animal. It is bilaterally symmetrical; the body is composed of a number of serially arranged segments, which are called **somites**, or **metameres**; the dorsal and the ventral sides of the body are unlike, the latter being characterized by the possession of a series of paired and jointed appendages metamerically arranged, that is, each somite, or metamere, bears a pair of appendages; the anterior and the posterior ends are also unlike, the former being characterized by the possession of organs of special sense and the mouth. The external covering of the body is a chitinous cuticula which constitutes an exoskeleton. All these features are equally characteristic of insects and myriapods.

As in all crustaceans, and also in insects, the body of the animal falls into three distinct divisions: the **head**, **thorax**, and **abdomen**. The first two of these body divisions do not, however, articulate freely with each other as they do in insects, but in common with all the higher crustaceans, they are fused together and form a single structure, which is called the **cephalothorax**. The dorsal and the lateral surfaces of this division show no segmentation, because of the fusion of the somites and the presence of a hard, shieldlike structure covering it, which is called the **carapace**, but on the ventral side the segmentation is distinctly seen. Extending along the entire ventral surface of the animal are the paired appendages. Their metameric significance may not be seen in the cephalothorax, but it will be distinctly seen in the

abdomen, where each somite except the last, or **telson**, bears a pair of appendages.

The animal is capable of two sorts of locomotion. By powerful strokes of the broad, finlike end of the abdomen it swims rapidly backward, and it can also walk on its thoracic legs. It is well provided with special sense organs. Most important to it are the two pairs of feelers, or **antennæ**, which are characteristic of all crustaceans, and the **compound eyes** on movable stalks. It also possesses, in a pair of small cavities on the upper surface of the basal joints of the first or shorter pair of antennæ, peculiar sense organs, which were formerly supposed to be ears, but are now known to be **balancing organs**. With the aid of them the animal maintains its equilibrium.

The body of the crayfish or the lobster, as of all the higher crustaceans, is made up of twenty somites, or body segments, of which the thirteen anterior somites form the cephalothorax, and the seven posterior ones the abdomen.

The Cephalothorax. The anterior five somites forming this body division are cephalic, the remaining eight are thoracic, and all are covered dorsally and laterally by the **carapace**. The projection running forward from the anterior end of the carapace is called the **rostrum**. A transverse groove is seen near its middle; this is the **cervical suture** and marks the boundary between the head and the thorax. In the crayfish two semicircular, longitudinal grooves extend backward from the outer ends of the cervical suture, which separate the sides of the carapace from the median, dorsal portion. The sides of the carapace are called the **branchiostegites**; they cover lateral folds of the dorsal integument of the animal, which extend over the sides of the body and inclose between themselves and it the spaces within which lie the **gills.** These spaces, the **gill chambers**, thus communicate freely with the surrounding water. Pass the handle of a scalpel or other flat object beneath the lower edge of the branchiostegite and it will go into the gill chamber. During life a current of water passes constantly into the gill chamber along this lower edge, where it bathes the gills and then passes out at the forward end.

Study the ventral side of the cephalothorax. The most important organs here are the appendages. At the anterior end of the body are the two pairs of **antennæ**, the longer pair being the second. On the lower surface of the basal joint of each of the latter is an opening; these are the external openings of the kidneys, or **green glands**. Back of the antennæ is the **mouth**. It is bounded in front by a liplike structure called the **labrum**, and at the sides by the strong **mandibles**. Press the mandibles aside and pass a probe into the mouth. Between the mouth and the large claws are five pairs of appendages which assist in the act of eating; they are two pairs of delicate leaflike **maxillæ**, just back of the mouth, and three pairs of larger **maxillipeds**, back of them. They are best identified by beginning with the hinder pair of maxillipeds, which is just in front of the large claws, and working forward, placing a needle or knife between the appendages as they are identified. Back of the maxillipeds come the large grasping claws, or **chelipeds**, which form the principal weapons of offense and defense of the animal, and in the largest lobsters are powerful enough to crush a man's arm. Note the difference between the right and the left claw, if any. Back of the chelipeds are four pairs of walking legs. In the male animal the paired external openings of the genital organs are at the base of the last pair of walking legs, in the female at the base of the third pair from the last. Find them.

The Abdomen. The seven somites forming this body division are all free and jointed with one another. Note the difference in the thickness of the cuticula on the dorsal and the ventral surfaces, also its thinness at the joints. The appendages on the abdomen have various uses. They probably have a general respiratory function. In the male the first two pairs are functional in pairing; in the female the first five pairs hold the eggs from the time they are laid until the young are hatched. The last pair in both sexes is large and broad and with the end segment forms the **swimming fin**. The end segment is called the **telson**; it bears no appendages; the **anal opening** is in its ventral side.

The natural color of the animal is usually a greenish black, but hot water or a preservative turns it red.

Exercise 1. Draw an outline of the dorsal side of the animal and label all the parts described above.

Cut off the right branchiostegite with the scissors, taking care not to injure the gills beneath. Push aside the gills and notice the thin integument which forms the lateral wall of the cephalothorax. Observe the method of attachment of the **gills**. They are feathery, thin-walled expansions of the body wall and are attached either to it or to the basal portions of the legs. They present a very large surface to the surrounding water, and the blood circulating through them is thus oxygenated. Notice the **epipodites**, the skinny flaps which project from the basal joints of many of the legs and separate the gills of a segment from those of the next. They are not prominent in the crayfish.

Exercise 2. Without displacing the gills or epipodites make a sketch of them as they lie in the gill chamber.

Exercise 3. Draw a diagram representing an ideal transverse section of the body wall in the region of the walking legs; show the relations of the branchiostegites, the legs, and the gills to the body.

The Appendages. Of these there are nineteen pairs, each somite of the body, with the exception of the last one, bearing a pair. There are thus thirteen cephalothoracic appendages, of which five are cephalic and eight thoracic, and six abdominal appendages. All these appendages, except the first pair, however much they may differ from one another, are modifications of a single primitive type of structure. This type has been least modified in certain of the abdominal appendages. We shall, consequently, study these first.

Exercise 4. The abdominal appendages are called **swimmerets** or **pleopods**. Cut off the right swimmeret of the fourth abdominal somite close to the body, draw it on a large scale, and label all its parts. It consists of a basal piece, the **protopodite**, and two terminal branches, the medial, or **endopodite**, and the lateral, or **exopodite**. This type of structure is characteristic of all crustacean appendages except the pair belonging to the first somite; those appendages which apparently differ from this type are modifications of it.

Exercise 5. Remove and draw on a large scale the right-hand sixth swimmeret. It is quite different from the last one drawn,

and is sometimes called a **uropod**, but yet has the typical parts. Label its parts.

Exercise 6, a. If the animal is a male, remove and draw the right-hand first and second swimmerets. These are modified from the typical structure to serve as copulatory organs.

Exercise 6, b. If the animal is a female, remove and draw the right-hand first swimmeret.

Exercise 7. The five pairs of walking legs (including the chelipeds) are called **periopods** and belong to the thorax. Remove and draw the right-hand fourth periopod, disregarding the gill attached to it, and label the parts. It consists of seven segments, of which the two proximal segments, those nearest the body, constitute the protopodite, and the five distal ones, those farthest from the body, the endopodite. The exopodite is not present.

Exercise 8. The **cheliped** is composed of the same segments as the other periopods. With a strong knife split the claw lengthwise into two equal halves. Examine the muscles controlling the movable limb of the claw. There is a strong **adductor muscle** which closes it, and a weaker **extensor muscle** which opens it. Make a diagrammatic drawing illustrating them.

Exercise 9. The three pairs of appendages directly in front of the chelipeds are the **maxillipeds**; they are thoracic appendages which assist in the process of eating. Remove with forceps and scissors the right-hand third (that is, the posterior) maxilliped; draw it on a large scale, disregarding the gill which may be attached to it, and carefully label the protopodite, exopodite, and endopodite.

Exercise 10. Remove with the forceps the right-hand second maxilliped and draw it on a large scale.

Exercise 11. Remove and draw the right-hand first maxilliped. The two large basal segments are the two segments of the leaflike protopodite, the endopodite is a very small structure next to the protopodite, and the exopodite is a much longer structure next to the endopodite. A large epipodite is present. Label all of these.

Exercise 12. The two pairs of delicate appendages in front of the maxillipeds are the **maxillæ**; they are cephalic appendages. Remove with forceps the right-hand second maxilla and draw a large outline of it. The protopodite is wide and leaflike; the endopodite is small; the exopodite is wide and with the epipodite forms a broad plate, called the **scaphognathite**, which is used by the animal to maintain a current of water from the gill chamber.

Exercise 13. Remove carefully and draw the right-hand first maxilla. The protopodite is wide and leaflike and similar to that of the second maxilla; the endopodite is extremely small; the exopodite is wanting.

Exercise 14. Extract with strong forceps and draw the right-hand **mandible.** The biting portion of it, together with the first joint of the small palp, forms the protopodite; the two terminal joints of the palp are the endopodite; the exopodite is wanting.

Exercise 15. Remove at its base and draw the right-hand second (the longer) **antenna.** The exopodite is a short, stiff, platelike expansion; the endopodite is the long, slender, terminal portion.

Exercise 16. Remove and draw the right-hand first antenna, or **antennule** as it is also called. No exopodite and endopodite are present in this appendage throughout the Crustacea, there being typically but one terminal branch. In the crayfish and lobster this terminal branch is double.

Exercise 17. Construct in your notebook a table showing the relation of the appendages and somites, as follows:

No. of Somite		Name of Appendage	Prot.	Ex.	End.
Head	1				
	2				
	3				
	4				
	5				
Thorax	6	First maxilliped	+	+	+
	7				
	8				
	9				
	10				
	11				
	12				
	13				
Abdomen	14				
	15				
	16				
	17				
	18				
	19				
	20				

Write opposite the number of each somite, in your notebook, first, the name of the appendage belonging to it, then indicate what parts that appendage possesses by a "+" and what parts it lacks by a "—" under the appropriate head, as is shown in the case of the sixth somite in the table on page 26.

The Gills. Remove the left-hand branchiostegite. Place the animal in water and study the gills on the left side. These organs may occur on the eight thoracic somites, and on each segment they may be attached either to the basal joint of the leg, when they are called **podobranchiæ**, to the flexible joint by which the leg articulates with the body, when they are called **arthrobranchiæ**, or to the body wall just above the leg, when they are called **pleurobranchiæ**. A single thoracic somite may bear on each side four gills, — a pleurobranch, two arthrobranchs, an anterior and a posterior, and a podobranch, — but on most of the somites a less number is present.

Exercise 18. Construct in your notebook a table showing the arrangement and number of the gills and also of the epipodites and their relations to the somites bearing them, as follows:

No. of Somites	Podo.	Ant. Arth.	Post. Arth.	Pleu.	Epip.	Total
6						
7						
8						
9						
10						
11						
12						
13						

Begin with somite 13 and indicate by a "+" under the proper head opposite the number of each somite the presence of the gill or epipodite, and by a "—" its absence.

The Internal Organs. With strong scissors and forceps carefully remove the shell from the entire dorsal surface of the animal, taking great care not to disturb the organs lying beneath. Notice just beneath the shell a pigmented membrane. This is the **underskin**, or **hypodermis**, the matrix of the shell. Entirely remove the

under-skin. Study the organs as they lie, without disturbing them. Notice in the cephalothorax, first, the large saclike **stomach** just back of the rostrum and connected by muscles with the anterior body wall. On each side of the stomach will be seen the cut ends of a mass of muscle fibers. These are the **mandibular muscles.** Demonstrate their connection with the mandibles. Just back of the stomach is the white, shield-shaped **heart**, from the anterior end of which five delicate **arteries** proceed, a median artery and two pairs of lateral ones. Find these arteries and trace them forward as far as possible without breaking them. On both sides of the stomach and the heart and partly beneath them are the **liver** and the **reproductive organs.** The former is a pair of large, soft, and usually light-green organs which may fill a large portion of the cephalothorax and may extend back into the abdomen. The latter, if the animal is a female, are a pair of brownish or yellowish organs, the **ovaries**, in which the ova can often be seen; they are situated beneath the heart and in front of and behind it, and vary in size and also in color with the development of the ova. When these are approaching maturity the ovaries are the most prominent organs in the body cavity, and often extend far back into the abdomen. In the male animal the reproductive glands, the **testes**, are white in color and very slender, and occupy the same position as the ovaries in the female. Note the coiled **sperm duct** on each side.

Study the musculature and the other organs of the abdomen. There are two systems of muscles here. On the dorsal side are longitudinal muscles, the **extensors**, which extend or straighten the abdomen. Separate these muscles carefully along the median line and observe beneath them the delicate, colorless **abdominal artery** which carries the blood from the heart throughout the abdomen. Trace it forward to the heart. Notice the lateral **branch arteries**. How many pairs are there? Just beneath this artery lies the **intestine**, which often contains dark-colored fecal matter. Beneath it and filling most of the space within the abdomen are the **flexor muscles**, which are very complex, and whose function it is to bend or flex the abdomen. It is by the use of these two sets of muscles that the animal swims.

Exercise 19. Draw an outline of the animal's body, showing the segmentation and the organs mentioned above, and label them all.

The Circulatory System. The **heart** lies within an inclosed space called the **pericardial sac**, the walls of which, the **pericardium**, will have been partially destroyed by the removal of the under-skin. The heart, the abdominal artery with its lateral branches, and the five anterior arteries have been studied and drawn. Carefully press aside the heart and note the median **dorsoventral artery** which leaves the abdominal artery near the heart and passes ventrally. This artery supplies with blood a **ventral longitudinal artery**, which lies in a midventral position in the thorax and abdomen.

Remove the dorsal abdominal artery and the heart from the body and float them in clean water. Note the six valvular openings of the heart, two being on the dorsal side, two on the ventral, and one on each of the lateral sides. These can be seen by blowing on the heart through a blowpipe.

Exercise 20. Draw a dorsal view of the heart showing the valves there present.

The course of the circulation of the blood is the following: by the contraction of the heart the blood is sent through the arteries to all parts of the body; after bathing the different tissues it collects in a space in the ventral portion of the body cavity in which lie the ventral nerve chain and the ventral abdominal artery, and passes toward the gills; from this space it then passes to the gills through afferent veins, one of which runs to each gill and along the outer edge of it; it then runs through the delicate gill filaments, where it is aërated, and passes by efferent veins on the inner edges of the gills back to their base; here six larger branchial veins collect the blood and carry it to the pericardial sac, whence it is taken through the valvular openings into the heart.

Exercise 21. Draw a diagram representing the entire circulatory system.

The Reproductive System: the Female Genital Organs. The position of the **ovaries** has already been observed. In the cray-

fish their forward portions are paired, and their hinder portions are fused and lie in the median line. In the lobster, however, no such fusion takes place, but the two ovaries are united by a bridge midway in their length. Find the paired **oviducts** which lead from the ovaries to the genital openings. Remove both ovaries and oviducts from the body and float them in water.

Exercise 22, a. Make a diagrammatic sketch of them.

The Male Genital Organs. The position of the **testes** has been already noted. In the crayfish they are similar in shape and position to the ovaries in the female animal, but are more slender; in the lobster they are a pair of long white tubes which extend forward as far as the stomach and back into the abdomen. Find the paired **sperm ducts**, which are long, convoluted tubes connecting the testes with the external genital openings. Remove the sperm ducts with the testes from the body and float them in a pan of water.

Exercise 22, b. Make a diagrammatic sketch of the male reproductive tract.

Cut open a sperm duct and examine its contents under a high power of the microscope. Star-shaped **spermatozoa** will be seen; if, however, the specimen has not been well preserved they will no longer be present.

Exercise 22, c. Draw a spermatozoön, if present.

The **digestive tract** consists of the **mouth**, **œsophagus**, **stomach**, **intestine**, into which open the paired **livers**, and the **rectum.** Pass a probe through the mouth into the stomach and notice the dorsoventral course of the œsophagus, which joins the mouth with the stomach. The paired ducts which unite the two lobes of the liver with the intestine join that organ just back of the stomach. Find them. With scissors sever the œsophagus just ventral to the stomach, taking care not to injure the brain, which lies in front of the stomach, or the two slender nerve connectives, which lie on either side of the œsophagus. Sever the rectum near the anus. Remove the entire digestive tract from the body and place it in a

pan of clean water. The liver is so soft that it may not be possible to remove it entire. Notice the boundary between the intestine and the somewhat larger rectum. In the crayfish the rectum is much longer than the intestine; in the lobster the opposite is true. In the lobster notice the **blind gut**, or **appendix**, which joins the rectum near its anterior end.

Exercise 23. Make a diagrammatic sketch of the digestive tract.

Cut open the stomach by a ventral incision and wash it out. Observe its chitinous lining and the dark-brown, chitinous teeth. This chitinous lining is a continuation of the cuticula which covers the external surface of the body and is molted with the cuticula. During certain parts of the year a pair of large, calcareous bodies called **gastroliths** are embedded in the lining of the stomach. They remain in the stomach after the molting of the cuticula and furnish lime for the new cuticula, which at once grows rapidly.

Exercise 24. Make a sketch of the inner surface of the stomach showing the teeth.

The Excretory System. Notice in the extreme forward end of the body cavity, just in front of and below the stomach, a pair of pale, greenish bodies. These are the kidneys, or **green glands.** Each one is made up of two portions, the smaller glandular portion, next to the body wall, and the larger saccular portion, or urinary bladder, next to the stomach. From the latter the **ureter** leads to the external openings which have already been noted.

Exercise 25. Draw a view of the forward end of the body cavity showing the kidneys as they lie in position.

The nervous system consists of a ventral double **nerve cord** lying in the midventral line in the body cavity and extending the length of the animal, with paired **ganglia** at intervals, also of a **brain** situated just back of the eyes, which is united with the ventral nerve by two **nerve connectives**, passing one on each side of the œsophagus. The ventral ganglia have typically a metameric significance, but many of the somites have lost their ganglia,

so that there are fewer ganglia than somites. The double nature of the ventral nerve is best seen in the thorax.

Remove all the muscles and the viscera from the body. The ventral nerve cord will be seen in the abdomen lying in the mid-ventral line. Notice the ganglia. How many do you count? Notice the lateral nerve branches. In the cephalothorax the nerve cord is concealed beneath transverse ridges of the ventral wall of the shell. Cut these with scissors and expose the nerve, beginning at the hinder end of the cephalothorax and working forward. How many thoracic ganglia do you find? Just back of the œsophagus is the large **subœsophageal ganglion** which is connected with the brain by the two connectives already mentioned. The **brain**, or **supraœsophageal ganglion**, is just back of the eyes.

Exercise 26. Draw an outline of the body and in it the nervous system, showing accurately the number of ganglia and the segments in which they lie, together with the lateral nerves.

Exercise 27. Draw a diagram representing an ideal sagittal section of the animal in which the relative position of the principal systems of organs is accurately shown.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Decapoda*

A CRAB

The crab is a representative of the more highly specialized of the two divisions of the Decapoda, the Brachyura, which include those decapods with short, weak abdomens. The lobster and the crayfish represent the other and less highly specialized of the two divisions, the Macrura, which comprise those decapods with long abdomens.

Compare the crab with the lobster or the crayfish. Note the broad, shield-shaped **cephalothorax** and the **abdomen** bent under it. The abdomen of the male crab is narrow and that of the female is broad. Which sex is your animal? In what ways is the higher specialization of the cephalothorax and the abdomen of the crab shown?

The body of the crab is composed of twenty somites, like that of the crayfish and the lobster, thirteen of which belong to the cephalothorax and seven to the abdomen. The cephalothorax is covered by a **carapace**. Notice the short, transverse suture which separates the cephalic from the thoracic portion. At the ends of this suture notice the longitudinal depressions which mark off the lateral branchial areas and separate the **branchiostegites** from the median portion of the carapace. The branchiostegites are not applied closely to the body as they are in the lobster and the crayfish, but stand out from it, very much increasing the transverse axis of the cephalothorax and making it longer than the longitudinal axis. This feature of its structure makes it easy for the crab to run sideways. Notice that the ventral edge of the branchiostegite is closely applied to the body, so that the respiratory water could hardly enter the gill chamber along this edge as it does in the crayfish and the lobster. An opening is present, however, at the base of the cheliped through which the water enters. Pass a probe into the branchial chamber through this opening. Notice the prominent stalked **eyes**; also the two pairs of delicate **antennæ**. Examine and identify the **mouth parts** and the **thoracic legs**; they will be found to correspond to those of the crayfish or

the lobster. Find the openings of the genital organs; in the male on the ventral surface of the last cephalothoracic segment and in the female in the third segment from the last.

The abdomen is relatively small and weak and usually remains folded beneath the cephalothorax. It lacks the swimming fin; crabs of most species cannot swim. The common blue crab, however, swims very well by means of the fifth pair of periopods. The number of abdominal segments is variable, fusion having taken place between certain of the somites. This number is also not the same in the male and the female of the same species. Raise the abdomen from the cephalothorax and observe the **swimmerets** on its ventral surface. In the female note the long chitinous hairs which fringe the swimmerets. It is to them that the eggs and newborn young are attached. The only swimmerets present in the male are the first two pairs, which are functional in pairing.

Exercise 1. Draw a dorsal view of the animal with the abdomen extended, being careful not to omit the antennæ and the eyes, and label all the parts observed.

Exercise 2. Construct in your notebook a table showing the relation of the appendages and somites similar to that made use of with the lobster or the crayfish. (See page 26.)

The Gills. With stout scissors cut off the right branchiostegite and expose the gills. These will be found to be quite different from those in the lobster or the crayfish, **pleurobranchiæ** only being present. Note the enormously elongated **epipodite** of the first maxilliped which extends across the gills to the hinder part of the branchial chamber.

Exercise 3. Construct a table showing the relation of the gills to the somites similar to that made use of in the dissection of the lobster or the crayfish. (See page 27.)

Exercise 4. Draw a diagrammatic cross section representing an outline of the body wall in the region of the walking legs; show in this the relation which branchiostegites, legs, and gills bear to the body.

Internal Anatomy. With strong scissors and forceps remove the shell from the entire dorsal surface of the body, taking care

not to injure the organs within. The arrangement of the organs will be seen to be similar to that in the crayfish or the lobster. The **livers** are a pair of extensive yellowish organs. The anterior portion of each of these passes laterally into the cavity of the branchiostegite; the posterior portion passes backward beneath the **heart.** In the male animal the **testes** are whitish organs which follow the course of the livers; the **sperm ducts** are slender, coiled tubes which lie on each side of the heart. In the female animal the **ovaries** also accompany the livers; the **oviducts** are a pair of tubes which pass to the genital openings, the middle portion of each being expanded to form a large sac, the **receptaculum seminis.**

Exercise 5. Draw an outline of the body and the organs as they lie in it. Label all carefully.

Remove all the viscera, taking care not to injure the brain and the circumœsophageal nerves, and examine the **nervous system.** The **brain** is just back of the eyes, as in the lobster or the crayfish, and is united with the ventral nerves by means of the lateral **circumœsophageal connectives** which pass on each side of the œsophagus. There is, however, no long ventral nerve cord with segmental ganglia, but a single **large ganglionic mass,** in the shape of a ring, which occupies a central position in the cephalothorax, and from which nerves radiate to the different appendages. The dorsoventral artery passes through this ring. Expose the entire nervous system.

Exercise 6. Draw a semidiagrammatic view of the nervous system, being careful to represent accurately the nerves radiating from the ganglionic ring and those going from the brain to the eyes and to the antennæ.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Isopoda*

A SOW BUG (*PORCELLIO, ONISCUS*, OR *ARMADILLIDIUM*)

This animal is one of the few terrestrial crustaceans. It may be found at any time of the year under stones, logs, etc., and in other moist, dark places, where it lives on decaying organic matter.

The animal must be studied with the aid of a hand lens or a dissecting microscope. Compare the animal with the crustaceans already studied. Notice the flattened body. It is composed of twenty somites, of which five are cephalic, eight are thoracic, and seven are abdominal, and much less fusion has taken place among them than is the case in the decapods. The head and the thorax are not covered by a carapace and thus are not joined together to form a cephalothorax. The apparent head is composed of six fused somites, five of which are cephalic and one thoracic. The remaining seven thoracic somites are free and movable. Count them. Count the abdominal segments. Six will be found, the last two abdominal somites being fused together.

Find the **eyes**: they are not on stalks, but are sessile. Only one pair of **antennæ** appears, the first pair being rudimentary. Notice the pair of **anal feelers** which extend back from the hinder end of the body. These are homologous to the last pair of appendages, like the cerci of orthopterous insects, and have a similar function, that of orienting the animal as to what is behind it.

Study the ventral side of the animal. Notice if it be a male or a female. The male has a long, dark-colored, tube-shaped **copulatory organ** which extends from the forward border of the abdomen backward. The female, besides lacking this organ, may have a **brood sac** on the ventral surface of the thorax, which is composed of plates attached to the medial side of the first five pairs of walking legs and contains eggs or young. Has your specimen a brood sac?

The Appendages. First observe the seven pairs of **walking legs**; they are the thoracic legs numbering from two to eight; gills are wanting in them. The **gills**, instead of being thoracic structures,

as in the decapods, are attached to the abdominal legs. With a fine needle separate the flattened appendages of the first five abdominal segments. The endopodite serves as the gill, while the exopodite is large and platelike and covers the endopodite.

Observe the appendages of the head. But one pair of antennæ will be seen, the second, the first pair being rudimentary in sow bugs; this feature is apparently an adaptation to a terrestrial life. The other mouth parts consist of one pair of mandibles, two pairs of very delicate maxillæ, and a pair of maxillipeds which are platelike and cover the other mouth parts. The maxillipeds belong to the first thoracic somite, which is fused with the five cephalic to form the head.

Exercise. Draw a dorsal view of the animal on a scale of 10. Number the thoracic and the abdominal segments.

MARINE BIOLOGICAL LABORATORY LIBRARY WOODS HOLE MASS.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Amphipoda*

A FRESH-WATER SHRIMP (*GAMMARUS*) OR A SAND FLEA (*TALORCHESTIA*)

The fresh-water shrimp is common in many places in pools and streams, and may be easily caught with a fine net; the sand flea is a marine animal and is extremely common along all of our shores.

Notice the compressed and translucent body; this latter feature is extremely widespread among the smaller aquatic animals. Can you explain what is the advantage to a small aquatic animal of being translucent or transparent? Note the two pairs of long **antennæ.** In common with all the higher Crustacea, the body is composed of twenty somites, of which five are cephalic, eight thoracic, and seven abdominal. Like the isopod, the animal has no carapace, the eyes are sessile, and the apparent head is composed of six fused somites, five being cephalic and one thoracic. There are thus seven free thoracic segments. Note the broad movable plates, the **epimeral plates**, which extend downward from the ventral side of certain of the thoracic segments; note the differences in form between the thoracic appendages. The abdomen is composed of six free segments, the sixth and seventh somites being fused. Count them. The first three pairs of abdominal legs are swimming legs, the last three are jumping legs.

Study the appendages, beginning with the free thoracic ones. With fine needles separate the legs and observe the **gills** attached to the posterior borders. How many bear gills? In the female observe the **brood sac** when it is present; it is formed by plate-like projections of the inner side of certain thoracic feet. In the abdomen observe the **biramous appendages**; they bear no gills. The cephalic appendages are those typical of Crustacea. In front of the mouth is a median lip called the **labrum.** Then come the **mandibles** and two pairs of **maxillæ.** The pair of appendages, the **maxillipeds**, belonging to the first thoracic somite (which is fused with the cephalic somites) form a kind of **lower lip.**

Exercise. Draw an outline of the side view of the animal on a large scale. Number the thoracic and the abdominal segments.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Amphipoda*

CAPRELLA

This is a very common marine amphipod which is found along our shores clinging to hydroid colonies or to seaweed. It is an interesting animal because it illustrates an extreme degree of modification from the typical amphipod type,—a modification which is the result of its mimicry of the form of the hydroid or seaweed on which it lives.

Notice the irregular, cylindrical form and the small number of appendages. The apparent head is composed of seven fused somites, of which five are cephalic and two are thoracic, the first of these latter bearing a pair of **maxillipeds**, and the second a pair of **legs**. There are thus six free thoracic segments, of which the first, fourth, fifth, and sixth bear legs which are without gills and the second and third bear gills but no legs. The abdomen has lost its segmentation and its appendages and has been reduced to a mere protuberance at the end of the thorax.

Exercise. Draw a large outline of the side view of the animal. Number the segments and label the parts observed.

CLASS: *Crustacea*. DIVISION: *Malacostraca*. ORDER: *Decapoda*

LARVAL DECAPODS: THE ZOËA OF THE CRAB; THE MEGALOPA OF THE CRAB; THE MYSIS STAGE OF THE LOBSTER

These names have been given to certain larval forms of the crab and the lobster, as well as to those of other of the higher crustaceans. It is as **zoëæ** that the crab and the higher crustaceans generally leave the egg. The zoëa of the crab grows into the **megalopa**, which in time grows into the adult animal. The stage in which the lobster is born is more advanced than the zoëa and is called the **mysis stage**. All of these larvæ are minute animals and are more or less common in the surface waters of the sea along the Atlantic coast.

Mount several **zoëæ** of the crab on a slide and study them under the microscope. The body will be seen to be divided into two body divisions, a **cephalothorax** and an **abdomen**. The former is covered with a delicate **carapace**, from which project one or more spines. When the animal is newly born it possesses the typical five pairs of cephalic appendages, and the anterior two or three pairs of thoracic appendages, that is, the maxillipeds, which, however, are used for locomotion. The remaining thoracic and the abdominal appendages are wanting, but appear as the animal increases in size, those anteriorly situated appearing first. The animal has two stalked eyes.

Exercise 1. Draw a side view of a zoëa on a large scale, representing accurately the appendages, and label the parts observed.

Mount a **megalopa** and study it under the microscope. You will observe that it is much larger than the zoëa, that it has acquired a relatively much larger cephalothorax and abdominal appendages, and is much more crablike than the zoëa. But it still has a long abdomen, and at the end of this is a swimming fin. The megalopa is a swimming animal, like the adult lobster, but it is gradually assuming the characters of the adult crab. Its two anterior maxillipeds have lost their locomotory character, which

they possessed in the zoëa, and have assumed their final form and function. Identify all the mouth parts.

Exercise 2. Draw a dorsal view of the animal, with the legs extended, on a large scale.

Mount several **lobster larvæ** in the mysis stage and study them under the microscope. The lobster is born in a more advanced condition than is the crab. The zoëa stage of the lobster is passed through in the egg, and when the young animal emerges from the egg it resembles Mysis, a schizopodous crustacean, and hence is said to be in the mysis stage. The general form of the animal does not differ much from that of the adult. The abdomen bears no appendages. The cephalothorax is very nearly like that of the adult and bears the same appendages. The third maxilliped, however, is a locomotory appendage, as it is in Mysis, and with the five periopods is used for swimming. Notice the biramous character of each periopod.

Exercise 3. Draw a side view of the animal on a large scale.

CLASS: *Crustacea*. DIVISION: *Entomostraca*. ORDER: *Copepoda*

A FREE-SWIMMING COPEPOD (*CYCLOPS*)

These minute animals are representatives of the division of Crustacea called the Entomostraca. All the crustaceans heretofore studied belong to the higher group called Malacostraca. Copepods are extremely common in both fresh and salt water. They may be obtained in almost any permanent pool of water in the woods or fields or from the surface water of the sea, often in large quantities, and are easily kept in aquaria. The animals should be studied alive if possible, and their swimming movements observed. They propel themselves, not by means of the feet, but by the long **antennæ**. It is the rowing motion of these organs which give the animals their jerky movements in the water. Place them on a slide under a cover glass with a few strands of cotton, and examine them under a microscope; in order to prevent the cover glass from crushing them it is well to support it with a little wax at two of the corners. If the pressure of the cover glass does not suffice to keep them quiet, the withdrawal of some of the water from under the cover glass with blotting paper will probably accomplish this result, but care must be taken not to let the water dry up.

Observe the cylindrical body and the two pairs of long **antennæ** with their sense hairs; also the long spines at the end of the abdomen. Note the division of the body into **abdomen** and **cephalothorax**, and also that the latter is not covered by a carapace. If the animal is a female it may be carrying a pair of **egg sacs** filled with eggs extending from the anterior end of the abdomen. Note the **median eye**, also the **intestine** and **muscle fibers**, through the transparent body wall.

The body is made up of fifteen somites, the **head**, **thorax**, and **abdomen** each containing five. The head is relatively large, and its somites are fused together; they bear the cephalic appendages common to all crustaceans. The first pair of **antennæ** is longer than the second; in the male it is secondarily modified to form clasping organs, by which the female is held during pairing. In

Cyclops, which is the commonest fresh-water genus of the Copepoda, the first thoracic somite is fused with the head, leaving only four free thoracic somites. The abdomen bears no appendages. In the female the first two abdominal somites may be fused together.

Exercise 1. Draw a large outline of the dorsal aspect of a copepod, not putting in any appendages except the antennæ. Represent accurately the sense hairs on the antennæ and the caudal bristles. Number the thoracic and abdominal segments and carefully label all the parts.

Study the appendages. The thoracic appendages are biramous. They do not bear gills, and the fifth pair is rudimentary. The cephalic appendages consist of two pairs of **antennæ**, one pair of **mandibles**, and two pairs of **maxillæ**.

Exercise 2. Draw a side view of an animal showing the appendages in position.

Exercise 3. Draw an outline of a thoracic leg on a large scale, showing accurately all the joints and hairs and its biramous form.

Compare the copepod with the young larva of the crab or the lobster. Enumerate the points of structural similarity between them.

Internal Anatomy. This can be best studied in the live animal. The **alimentary tract** is straight and of large diameter, and often contains dark-colored fecal matter. The **mouth** has a ventral position, as in other crustaceans, and the **anus** is dorsal. There is no liver or other accessory glandular organ. The **circulatory system** in Cyclops consists of the colorless blood fluid alone, there being no heart. The blood is, however, kept in circulation by the rhythmic contractions of the intestine. Other copepods possess a dorsal heart. There are no special respiratory organs, respiration being effected through the body wall. The **excretory system** consists of a pair of coiled kidney tubes, called the **shell glands**, which lie in the forward part of the cephalothorax.

The **reproductive system** consists of median or paired organs in the dorsal portion of the cephalothorax above the intestine. In the female the **ovaries** are often conspicuous as a pair of large

branched organs. The **oviducts** are paired and lead to the external sexual openings in the first abdominal segment. Appended to the first abdominal segment may be a pair of **egg sacs** containing fertilized eggs which are cemented together by means of a secretion of the oviduct. In the male the reproductive gland is the median **testis**, which communicates by means of paired sperm ducts with the external sexual openings, which are also in the first abdominal segment. The spermatozoa collect in the terminal portion of each sperm duct and form there a small mass known as a **spermatophore**. The two spermatophores, during the act of pairing, pass to the female and fertilize the ova. The male animals are much less numerous than the females.

The reproductive glands of the copepod can be observed as above described only during times of sexual activity. At other times they can be seen only in part or not at all.

The **muscular system** can be easily seen to consist of striated muscle fibers. Longitudinal as well as converging fibers will be seen at each appendage.

The **nervous system** may be seen in favorable specimens as a ventral strand in the cephalothorax connecting with the large dorsal **brain.**

Exercise 4. Draw a side view of the animal, showing as many of the internal organs as you have observed.

CLASS: *Crustacea*. DIVISION: *Entomostraca*. ORDER: *Phyllopoda*

A DAPHNID

The Daphnidæ are a family of small fresh-water crustaceans common in lakes and pools. They should be studied under the microscope and alive if possible. Place one or more on a slide with a few strands of cotton under a cover glass two corners of which are supported by wax, and draw off enough water to keep them quiet; also observe several in a watch glass. The body of the animal will be seen to differ in shape from those crustaceans already studied. It is but indistinctly segmented, and, except the head, is entirely covered by a bivalve shell. This shell is the cuticular covering of paired folds of the dorsal integument, one fold covering each side of the body. Beneath the opening of the valves of the shell appear the **appendages** and the **abdomen**; on the surface of the shell a meshwork of fine lines can usually be seen. Notice the large, median **eye**; it may often be seen to tremble slightly. The shell has a deep, ventral indentation near the base of the antennæ.

The **first pair of antennæ** is very small, but may be easily seen projecting downward just back of the eye. The **second pair of antennæ** is very long and biramous, the two branches being the exopodite and endopodite; they are the principal organs of locomotion. Just back of the antennæ is a large flap, called the **upper lip**, and back of this are the large **mandibles**. There is but a single pair of **maxillæ**, and they are so small that they will probably not be seen. Four to six pairs of **thoracic appendages** follow, the function of which is probably exclusively respiratory. How many are present in your specimen? Notice the leaflike surface of these appendages (whence the name Phyllopoda) and their complex form. The short abdomen articulates with the thorax and is bent beneath it, where it may be seen often moving rapidly back and forth.

Exercise 1. Draw an outline of a side view of the animal on a large scale and label the appendages and other parts observed.

Internal Organs. The **digestive tract** passes from the mouth, which is ventrally placed and lies back of the ventral cleft in the shell, first forward, then turns dorsally and finally posteriorly and extends back to the **anus** near the end of the abdomen. Near the anterior bend of the digestive tract a pair of colored, curved pouches communicate with it; they are the **livers.** The saclike **heart** may be seen beating rapidly above the intestine. It possesses a pair of lateral openings into which the blood streams from the body cavity with each dilation, and an anterior opening through which it is sent into the forward part of the body with each contraction. There are no other blood vessels.

The Reproductive Organs. The daphnids which are usually seen are all parthenogenetic females, the males making their appearance at certain times of the year only. The female animal is larger than the male, and may be distinguished by its **brood sac.** This is a large space just beneath the dorsal wall of the thorax in which the eggs and the young brood are carried. The **ovaries** are a pair of tubular organs alongside the intestine, which communicate, by means of short **oviducts,** with the brood sac. The ovaries are easily detected by the presence of large ova in them. These are in groups of four, of which but one, the third, is destined to become an egg, the other three being nutritive cells by which it is nourished.

During the greater part of the summer the eggs pass into the brood pouch unfertilized and develop there parthenogenetically, producing only females. The young animals pass out of the brood chamber through a posterior opening; they soon become adult and in their turn give birth to parthenogenetic females. The eggs which thus develop are called **summer eggs.** At certain times of the year, however, as in the autumn, males are also born. They fertilize the females, and the fertilized eggs then produced differ from those which were unfertilized in possessing thicker shells. They are called **winter eggs** and are able to resist the cold of winter or the effect of drought. In the spring the winter eggs develop into parthenogenetic females again.

Exercise 2. Draw an outline of the animal and place in it all the internal organs you have observed.

CLASS: *Crustacea.* DIVISION: *Entomostraca*

A NAUPLIUS LARVA

In an aquarium containing copepods or ostracods there are sure to be numbers of the young larvæ of these animals. They are minute, free-swimming forms and are called **nauplii**, and may be recognized by the triangular or oval, unsegmented body, which bears three pairs of appendages and a median eye. Nauplii of marine entomostracans may also be met with in large numbers among the small animals obtained by skimming the surface waters of the sea with a fine net.

Examine in a watch glass under a microscope water containing sediment taken from a jar in which are copepods or ostracods. Find a nauplius; the ostracod nauplius differs from that of the copepod by being inclosed in the characteristic bivalve ostracod shell. If marine plankton is at hand, look for several kinds of nauplii in it.

Study the structure of a nauplius. Observe the unsegmented body; if the animal is not newly born, signs of segmentation may have begun to appear. Observe the three pairs of segmented appendages; the segmentation, however, is often indistinct. These appendages are homologous to the **first** and **second pair** of **antennæ** and the pair of **mandibles** of the adult animal. As in the adult, the first pair is uniramous; the second and third pairs are biramous. Both of the latter two pairs are used for locomotion, although it is probable that they also act as jaws. The **median eye** will be seen, and the straight **digestive canal.**

Exercise 1. Draw a nauplius on a large scale and label all the parts above mentioned.

The nauplius larva is of great theoretical significance. It appears as the youngest, free-swimming, larval stage of almost all the entomostracans and of several of the malacostracans, and those malacostracans which are born in a later period of their development pass through a nauplius stage (that is, a stage in which the body is unsegmented and bears three pairs of append-

ages) while they are still in the egg. This universal occurrence of the nauplius larva seems to indicate that it repeats substantially the structure of the primitive ancestor of all crustaceans.

In its further development and growth the nauplius larva increases in size, gradually becomes segmented, and acquires new appendages, its growth and the specialization of its organs advancing from the anterior toward the posterior end. The appendages, which were originally typical, unmodified crustacean appendages, become differentiated to form the first and second pairs of antennæ and the mandibles, and finally the size and structure of the adult are attained.

Exercise 2. Look for several nauplii which are somewhat advanced in development and draw outlines of them.

PHYLUM ANNELIDA

CLASS: *Chætopoda*. ORDER: *Polychæta*

THE SANDWORM (*NEREIS*)

Nereis is a common marine worm which lives in the sand along the shores of our northern and middle states. Its food consists of various kinds of small marine animals, which it catches with its formidable, protrusile proboscis. A specimen should be selected for study in which the proboscis is not thrust out.

Observe, in the first place, the long, segmented, and somewhat flattened body, the pair of appendages on each segment, and the distinct head with special sense organs at the forward end; observe also that the body tapers toward the hinder end, where is a pair of special sense organs, the long caudal feelers. All these characters indicate an animal possessed of the power of rapid locomotion. Count the **somites**, or body segments; note that they are almost exactly alike. This lack of specialization is in sharp contrast to the condition of the somites in most arthropods. Observe carefully the appendages; they differ from those of the arthropod in that each one is an unjointed expansion of the body wall, whereas the arthropod appendage is segmented. Each one is made up of several lobes and is provided with long bristles, or **setæ**. Note the absence of a hard shell, the external integumentary covering being the glistening cuticula, which has not been stiffened by the presence of calcareous salts.

Observe the head and the forward portion of the body. An annelid's body is composed genetically of two portions: the **prosoma**, or primitive head, and the **metasoma**, or the primitive, segmented trunk. The prosoma may be further divided into the **prostomium**, which lies in front of the mouth and contains the brain and the principal organs of special sense, and the **metastomium**, which contains the mouth. In Nereis the prostomium

bears the following special sense organs: a pair of **palps**, large cylindrical projections extending forward at its anterior end; a pair of **tentacles**, two delicate organs between the palps; and two pairs of **eyes**, small, beadlike organs near the base of the palps. Carefully identify all these organs and notice whether the palps and tentacles are jointed. The metastomium is, in Nereis, fused with the first two somites of the metasoma, or trunk, and the segment thus formed is called the **peristomium**. It bears the mouth and four pairs of long, flexible sense organs called the **peristomial cirri**. Carefully observe, with the aid of a hand lens, their exact position. These cirri are morphologically not cephalic organs, as are the palps and the tentacles, but are remnants of appendages of the first two somites.

Exercise 1. Make an outline of the dorsal aspect of the head and the first five or six somites on a scale of 5. Number the somites. Carefully label all the parts.

Exercise 2. Draw a side view of the head on a scale of 5. Take special care to represent accurately the position of the peristomial cirri.

Exercise 3. Find a specimen, if possible, with the proboscis thrust out and draw a dorsal view of its head.

Note the tapering of the body at the hinder end. The worm grows in length at this end. The posterior somites are the youngest and hence the smallest.

Exercise 4. Make a sketch of the hinder end of the animal. The long sense organs at the extreme end are called **caudal cirri**. In which direction do they project?

The appendages in annelids are called **parapodia**. Carefully examine the parapodia at different parts of the body and see if they are all alike.

Remove a parapodium from the middle of the body; mount it on a slide in water and study it with the aid of a hand lens or a microscope. Compare it with the parapodia still on the animal and determine which is its dorsal and which its ventral side. It can be divided into two distinct portions, the dorsal and the ventral portions, called the **notopodium** and the **neuropodium**, respectively, each of which is stiffened by an internal, chitinous,

supporting rod, called the **aciculum**. Find the two acicula. The large dorsal lobe of the notopodium is a respiratory organ, **a gill**. It contains branching blood vessels which can be easily seen. Attached to its dorsal edge is a slender, vibratile sense organ, the **dorsal cirrus**. Beneath the gill are two lobes, one bearing bristles, or **setæ**. The neuropodium is made up of two lobes, one of them setæ-bearing, beneath which is a **ventral cirrus**.

Exercise 5. Draw a parapodium on a scale of 6 and label the parts.

Internal Anatomy. Make an incision with fine, sharp scissors in the mid-dorsal line of the integument of the anterior third of the animal, taking great care not to injure the viscera which lie beneath. The body cavity, or cœlom, will be seen to be divided into compartments corresponding to the somites, by transverse partitions which are called **septa**. Holding the cut edge of the integument with forceps, cut the septa where they join it, and then spread out and pin down the body wall, using many pins on each side.

The Digestive Organs. The **mouth** leads into the large **pharynx**, which is composed of an anterior and a posterior portion. With sharp scissors cut open the pharynx along the mid-dorsal line and note the number and arrangement of the chitinous **teeth** embedded in its inner surface. Notice the delicate muscles passing from it to the body wall, by means of which the pharynx can be thrust out of the mouth and drawn back again. They are the **protractors** and the **retractors**. A pharynx which is thus protrusile is called a **proboscis**. Just back of it is the narrow **œsophagus** with which a pair of small tubular **glands** communicate. Back of the œsophagus is the **stomach intestine**, which extends to the **anus**. Observe the **mesenteries**. These are longitudinal partitions, in structure like the septa, one of which attaches the stomach intestine to the dorsal and the other to the ventral body wall. Press the intestine aside and see the ventral mesentery.

The Circulatory System. Nereis has two distinct circulatory fluids, the colorless, or cœlomic, and the red blood fluid. The first consists of a plasma in which float amœboid blood cells; it circulates freely in the body cavity, or cœlom, being forced by the

movements of the body from one segment to another through small openings in the septa. The red blood consists of a red plasma, in which float colorless blood cells, and circulates in closed tubes. The most important of these blood vessels are two longitudinal tubes, the dorsal and the ventral arteries, which lie in the median line, one above and the other below the alimentary canal. The former, the **dorsal artery**, pulsates and drives the blood toward the forward end of the body and distributes it to lateral **segmental arteries**. Observe these and determine how many there are in each segment; also note the capillary **network** into which the dorsal artery breaks up at its anterior end. The dorsal portions of the lateral arteries carry the blood to the gills and other organs, whence it collects again in the ventral portions of these arteries and is conducted to the **ventral artery**. In this vessel the blood flows toward the hinder end of the body.

Exercise 6. Draw a view of the opened animal on a scale of 5, showing the organs above described. Label all the organs carefully.

Sever the alimentary tract at the œsophagus and remove the stomach intestine from the body. Observe the **muscle bands** in the body wall; note the difference in direction and size of the different bands. Observe the muscles at the base of the acicula.

The Excretory System. The **kidneys** of the animal consist of a pair of very slender, tortuous tubes called **nephridia**, which lie in the body cavity against the ventral body wall in each somite except the last two or three; they are difficult to see because each is covered with a mass of jellylike connective tissue. Each nephridium opens through the body wall to the exterior in a minute pore on the ventral surface of each somite near the base of the parapodium. The anterior end of the nephridium passes through the septum which forms the anterior wall of the somite in which that organ lies, and opens into the body cavity. The opening, which is ciliated, is called the **nephrostome**; it lies against the anterior surface of a septum.

The Nervous System. Observe in the midventral line of the body cavity the **nerve cord**. Trace it forward to the **brain**. Note the **connectives** which encircle the pharynx and connect it with

the brain. Remove the forward end of the nervous system from the body, mount it in glycerine, and study it under a microscope. Note the **ganglionic enlargements** and the double nature of the nerve cord. Study the branches which pass off from the nerve cord and from the brain.

Exercise 7. Draw a diagram representing the opened body cavity in a number of somites on a scale of from 5 to 10, showing all the above-mentioned features which have been observed.

The Reproductive System. There is no complicated reproductive system in Nereis. The sexes are separate. The reproductive glands make their appearance only during the periods of sexual activity and then as swellings of the peritoneal lining of the body cavity. The eggs or spermatozoa, as the case may be, fall into the body cavity and find their way to the outside through the nephridia or through ruptures in the body wall.

Exercise 8. Draw a diagram representing an ideal cross section in the region of the stomach intestine; show the stomach intestine with its mesenteries, the blood vessels, the nerves, and the muscles.

CLASS: *Chætopoda.* ORDER: *Oligochæta*

AN EARTHWORM

The earthworm is, to most people, the most familiar annelid. It is distributed over the entire earth, the United States possessing several species. The animal is nocturnal in its habits. It lives in long burrows in the ground, in which it lies during the day and the inclement seasons of the year. Its food consists of leaves and other vegetable substances and also of the organic matter contained in the soil which passes through its alimentary canal.

First study the animal alive, if possible, but also have one at hand which has been killed in very weak alcohol. Notice its color, its cylindrical, elongated body, its very small, pointed head, and the absence of appendages, — all of which characteristics are correlated with its burrowing life. Note also the absence of a hard shell, the external integumentary covering being the glistening cuticula. As the animal lacks appendages, locomotion is accomplished by means of body movements. Place the animal on moist filter paper or a piece of moist newspaper and study its method of locomotion. It will be observed successively to elongate and to shorten its body, which of course would be impossible if it were covered by a hard shell. Notice that along the ventral and the lateral surfaces are several rows of minute bristles, the **setæ**; they aid in locomotion and are under the control of muscles. Determine, by passing the animal through the fingers and with the aid of a hand lens, how many rows there are and their relation to the segments. Determine also whether the setæ at the forward end of the body project in the same direction as those at the hinder end. Observe carefully the importance of the setæ in locomotion.

The animal is segmented externally; that is, it is made up of a number of **somites**, or **metameres**, like the crustacean body. Count the somites, beginning with the segment just back of the mouth, which is the first somite. Notice the close similarity of the somites. This lack of specialization is always a primitive

character in a segmented animal and is in sharp contrast to the condition of the somites in most arthropods.

Notice the moist, slimy surface. Moisture is necessary to the animal's existence; this accounts largely for its nocturnal and subterraneous habits. Notice also the red blood vessels through the semitransparent body wall. What movement of the blood can you detect? What are the differences between the dorsal and the ventral surfaces? Notice the difference between the anterior and the posterior ends. The forward end is the older; the animal grows in length by adding new somites to the hinder end. Notice the ventral position of the **mouth** and the terminal position of the **anus**; note also the thickened ring around the body not far from the forward end. This is the **clitellum**; its function will be explained in speaking of the reproductive organs. The animal is without organs of special sense; numerous minute, tactile sense organs which are sensitive to light and other stimuli are, however, present. These are distributed along the body but are especially abundant toward its anterior end. Note the greater sensitiveness of this part of the body.

The head of the animal may be divided into two portions: the **prostomium**, the median dorsal projection overhanging the mouth, and the indistinct **peristomium**, which contains the mouth and is marked off from the prostomium by fine, transverse lines. What somites are included in the clitellum? On the ventral surface of the fifteenth somite a pair of prominent, transverse slits will be seen. They are the external openings of the **sperm ducts**. On the fourteenth somite look with the hand lens for the two minute openings of the **oviducts**; they are difficult or impossible to see except during the reproductive period of the animal. Other external openings in the ventral surface which are usually too small to see are the following: the two pairs of openings of the sperm receptacles between the ninth and tenth and the tenth and eleventh somites; and those of the kidney tubules, or **nephridia**, which open through the body wall to the exterior by minute pores on either the ventral or the lateral side near the anterior border of the somite. Look for them with a hand lens.

Exercise 1. Make a sketch on a scale of 3 of the ventral aspect of the forward end of the animal back to the posterior border of the clitellum. Indicate the somites and number them.

Exercise 2. Make a similar sketch of the ventral view of the last four somites on a scale of 3.

Internal Anatomy. Pin a large worm, which has been killed, firmly to the wax of the dissecting pan by a strong pin at each end; then make an incision with fine, sharp scissors through the integument in the mid-dorsal line from the forward end of the animal to a point back of the clitellum, taking great care not to cut the viscera lying beneath. It will be noticed that the body cavity is divided into compartments, corresponding to the somites, by transverse partitions, which are called **septa**. Holding the cut edge of the body wall with the forceps, cut the septa where they join it; then spread out and pin down the body wall, using many pins on each side.

Observe first the large **alimentary canal**, which passes straight through the animal; also several pairs of conspicuous white bodies a short distance from the anterior end, which are the **sperm sacs**. If the specimen has been freshly killed, the red blood vessels will also be seen. Study and identify in detail the following systems of organs.

The Circulatory System. The earthworm has two circulatory fluids, a red one and a colorless one. The latter consists of a plasma in which float amœboid blood cells. It is present only in the body cavity and circulates throughout the body, being driven by the movements of the animal from one somite to another through small openings in the septa; it will, of course, not be visible in a dissection. The red blood consists of a red plasma in which float colorless blood cells, and it circulates in a system of closed blood tubes. The most important of these blood vessels are two longitudinal vessels and numerous circular ones. Observe the **dorsal longitudinal vessel** in the median line, above the alimentary canal. It is contractile and propels the blood toward the head. Push aside the intestine and observe just beneath it the **ventral vessel**, which runs parallel to the dorsal one. Notice that these vessels break into small branches at their anterior ends.

The circular or **commissural blood vessels** connect the dorsal and the ventral vessels and have a paired and segmental arrangement. They are not all of equal size. Observe the four or five large pairs near the forward end of the animal, which pass directly between the dorsal and the ventral vessels. They are, like the dorsal vessel, contractile and are sometimes called the **hearts.** In which somites are they? Find the **commissural vessels** posterior to them. These are much smaller and do not pass directly between the longitudinal vessels, but break into capillaries between them.

The Digestive System. The **pharynx** is an oval, muscular pouch occupying four or five somites directly back of the mouth; radiating muscle fibers join it with the body wall. The **œsophagus** is a slender tube following the pharynx and running between the conspicuous sperm sacs to the **crop** in about the fifteenth somite. Press aside these sacs and notice beneath them three pairs of white glands; these are lateral diverticula of the œsophagus and contain calcareous crystals which have a digestive function. The **crop** is a thin-walled dilation of the œsophagus which lies about in somites 15 and 16, close to the **gizzard**, a muscular, thick-walled chamber of the same size as the crop and lying in somites 17 to 19. This is followed by the **stomach intestine**, a large tube with lateral segmental pouches, which passes to the hinder end of the body; covering the surface of the stomach intestine is a loose mass of yellowish-brown cells, the **chloragogue cells**, whose function is unknown.

Exercise 3. Make a drawing of the opened animal on a scale of 3, showing the segmentation and representing the organs above described in their proper somites; label all carefully.

Sever the alimentary tract just back of the pharynx and remove it from the body.

The Reproductive System. The earthworm is hermaphroditic and possesses the following genital organs:

The Male Organs. (1) **The sperm sacs.** These have already been noticed. They are large, white, irregularly lobed sacs occupying somites 9 to 13; they vary in size with the sexual condi-

tion of the animal, being largest during periods of sexual activity. (2) **The testes.** Two pairs of these organs are present, which lie beneath the sperm sacs in the tenth and eleventh somites; they are very minute objects and will not be seen. (3) **The sperm ducts.** These are a pair of slender white tubes which extend from the sperm sacs to the fifteenth somite, where they open, through the conspicuous transverse slits already noticed, to the exterior. Look first for the posterior portion of these tubes and trace them forward. The spermatozoa pass from the testes, where they but partially develop, into the sperm sacs, in which their development is completed and where they are grouped together in balls. From here they pass, during pairing, into the sperm ducts, and out of the animal through the slitlike openings in the fifteenth somite.

The Female Organs. (1) **The sperm receptacles.** These are two pairs of spherical white sacs beneath the sperm sacs in the ninth and tenth somites; they are easily seen. (2) **The ovaries.** These are a pair of extremely small organs lying near the median line and attached to the anterior septum of the thirteenth somite near the ventral body wall; they will hardly be seen. (3) **The oviducts.** These are two minute, funnel-shaped tubes which extend from immediately behind the ovaries through the septum to the external opening in the next somite; they will also hardly be seen.

During the months of May and June earthworms meet and pair in the nighttime. Two animals place themselves alongside of each other, headed in opposite directions and in such a way that the sperm receptacles of each come opposite the openings of the sperm ducts of the other, and are held firmly together by the secretion of glands in the integument. The sperm receptacles of each are then filled with spermatozoa from the other animal. The worms then separate. Sometime later the clitellum secretes a viscid fluid which hardens and forms a tough, cylindrical membrane around the body. The worm then squirms backward, causing this membrane to pass forward toward its head. As the membrane passes the fourteenth somite, eggs are poured from the oviducts into the viscous mass which is held between it and the body, and at the tenth and eleventh somites spermatozoa pass

in from the sperm receptacles and at once fertilize the eggs. The cylindrical membrane then passes completely off the worm and its two ends close together. It forms thus a yellowish, spindle-shaped capsule about as large as a small pea, which is called the **cocoon**. In it the young animals are born.

Excretory Organs. These are the kidneys of the animal. They consist of a pair of coiled tubules, called **nephridia**, which lie near the lateral and ventral wall of the body cavity in each somite, except the first three or four and the last one. Each nephridium has two openings, a funnel-shaped, ciliated opening into the body cavity, called the **nephrostome**, and one through the body wall to the outside. The former in each case is attached to the anterior side of a septum. The tube passes backward through the septum to the next somite, in which the greater portion of it lies, and through the wall of which it communicates with the outside. The distal, middle, and proximal portions of the tube differ from one another. The **distal portion** (that next to the nephrostome) is very slender; the **middle portion** is much thicker and has glandular walls; and the **proximal portion** is a dilated tube which probably acts as a **urinary bladder**.

Exercise 4. Make a sketch of somites 8 to 20, representing diagrammatically the reproductive organs and two or three pairs of nephridia lying in their proper somites, and label all.

Crush the sperm sacs of a fresh worm, which has not been in alcohol, mount some of the milky fluid in it, and examine it under a compound microscope. Notice the **sperm spheres** and **spermatozoa**.

Exercise 5. Draw a sperm sphere and a spermatozoön.

With a sharp knife or curved scissors carefully remove as much of a nephridium as possible from the animal's body. Mount it on a slide and examine it under a microscope.

Exercise 6. Draw it and label its divisions so far as observed.

The **nervous system** is essentially similar to that in arthropods. It consists of a double cord joined by segmental, paired ganglia; the two cords are so closely bound together that they appear as

a single strand. Remove the sperm sacs and observe the **nerve cord** as it lies in the midventral line. Note the slight swellings; these are the **segmental ganglia**. Trace the nerve cord forward to the region of the mouth, where it encircles the forward end of the pharynx and joins the small **brain.** Observe the two ganglia of which the brain is composed. Remove the forward portion of the nervous system from the body. Mount it on a slide and examine it under a microscope. Note the double nature of the nerve cord and of the ganglia. Note accurately the lateral branches that leave the cord; note also the shape and branches of the brain.

Exercise 7. Draw the nervous system on a large scale, accurately representing all the details.

Study of a Cross Section. This is instructive because it shows the relations of the organs to one another in their natural positions and also illustrates their finer structure. A properly stained and mounted cross section of any portion of the body will serve for this study.

Observe first the **integument**; it is made up of the **cuticula** on the outside and the cellular **hypodermis** beneath it. The latter is composed, in most parts of the body, of a single layer of cells which secretes the cuticula. Note the numerous single-celled **glands** in the hypodermis. If the section passes through a **seta,** notice its method of attachment and its muscles. Beneath the integument are the body muscles. Of these there are two systems, the **circular** and the **longitudinal muscles**. The former are a narrow band just beneath the hypodermis. The latter are much more extensive and project into the body cavity; they are arranged in groups and will be seen of course in cross section. Near the center of the body cavity note the large **alimentary canal.** If the section is in the region of the stomach intestine, note the longitudinal fold in the dorsal intestinal wall which very largely increases its surface. Observe the structure of the alimentary canal; its cavity, or lumen, is bounded by a thick mucous membrane consisting of a single layer of very long, slender cells, around which are two muscle layers, an inner **circular** and an

outer, very thin, **longitudinal** layer. Surrounding the muscle layers and also forming a thick fold over the dorsal and lateral intestinal surfaces are the pear-shaped **chloragogue cells**. Observe the **dorsal** and the **ventral blood vessels**, and also the **commissural blood vessels**, if any are in the section. Study carefully the **nervous system.** Note the **muscular sheath** which surrounds the nerve cord, and embedded in it the sections of three minute, longitudinal **blood vessels**. Note the double nature of the nerve. Note the large, pear-shaped **nerve cells** and the **nerve fibers**, also the three large bodies in the dorsal portion of the ganglion. These latter are called the **giant fibers**. Do lateral nerves join the ganglion? If so, trace their fibers into it. Also trace their fibers away from the ganglion and see where they go. Examine carefully the **peritoneum**. This is a layer of cells which lines the body cavity and bounds all the organs in it.

Exercise 8. Draw the cross section and carefully label all the organs.

PHYLUM VERMES

SUBPHYLUM PLATYHELMINTHES

CLASS: *Turbellaria*

A PLANARIAN WORM

Planarian worms are very common animals in fresh-water streams and ponds as well as in the sea; they may be found on the under-side of stones or on aquatic vegetation. They are flat, elongated, very soft, and contractile animals, brownish or yellowish in color, and usually half an inch or less in length; at the forward, broader end is a pair of lateral sensory lobes called the **auricles**, and on the dorsal surface are two black eyes; the hinder end is pointed. A variety of forms is found, some of which are very minute and are without an intestine or have a straight, tubular intestine, whereas others are much larger and have a branched intestine. The latter include most of the commoner turbellarians and those for which these directions have been prepared.

Study the live animal under a hand lens. Note the gliding motion with which it moves. This is accomplished partly by the action of the cilia which cover its surface and partly by muscular contraction. Near the middle of the ventral surface are the **mouth** and the protrusile **proboscis**. Mount the animal on a slide in water beneath a cover glass and observe the action of the cilia under a compound microscope. Note also the **rhabdites**, minute rods which are thickly set in the integument.

Exercise 1. Draw an outline of the animal on a large scale, with the eyes and proboscis, and indicate its anterior and posterior ends.

Study an animal which is under the pressure of a large cover glass, and make out as many of the following organs as possible, using often reflected instead of direct light.

The Digestive System. The digestive canal is usually easily

seen. The **mouth** is a circular opening near the center of the ventral surface; it leads into the **pharynx**, a cylindrical organ with thick, muscular walls, which can be thrust out of the mouth as a proboscis. At the base of the pharynx the **intestine** divides into three trunks, one of which passes forward and the other two backward to the extremities of the animal's body. Each of these trunks gives off lateral branches which are themselves often branched. There is no anus.

Exercise 2. Draw an outline of the animal and place in it the digestive system in detail.

The Reproductive System. Planarians are hermaphroditic; the sexual organs are complicated in structure and arrangement and difficult to observe in a live specimen. Near the lateral edges of the body will be seen, among the ends of the lateral intestinal branches, two sets of lobed organs. Of these the larger are the **yolk glands**, which connect with the **oviducts**; the smaller and less apparent ones are the rounded **testes**. Just back of the mouth is the **uterus**, which is often to be recognized by the spherical eggs it may contain; it passes back to a sac called the **genital cloaca**. The **ovaries** are a pair of spherical bodies in the anterior part of the body, and from them a pair of **oviducts** extends to the hinder part of the body, receiving the lateral yolk glands on their course. Leading from the **testes** are the **vasa efferentia**, very delicate tubes, which pass to the conspicuous **vasa deferentia**. There is a pair of the latter organs, one on each side of the mouth and pharynx; they extend to the hinder part of the animal, where they unite to form the muscular **cirrus**, which opens into the genital cloaca. The two **oviducts** also fuse at their hinder ends, and the median duct thus formed opens into the **genital cloaca**. This structure, which thus receives all the ducts from the genital glands, communicates with the outside through the **genital pore**, a median, ventral opening in the hinder part of the body.

Exercise 3. Draw a large outline of the animal and place in it as much of the reproductive system as you have observed.

The Nervous System. Beneath the eye spots will be seen the opaque **brain**, a large nervous mass consisting of a pair of minor

masses united by a broad commissure. From its anterior and lateral sides numerous **sensory nerves** pass to the anterior body surface, which render this extremity a highly sensitive tactile organ. From its posterior side a pair of large **longitudinal nerve cords** passes to the hinder end of the body, being united at intervals by **transverse nerves.**

The Excretory System. This is difficult to see; it consists of minute tubes which extend throughout the body and collect the excreted matters from the tissues. There are two main **longitudinal tubes** extending the length of the body, which open to the outside through minute pores on the dorsal surface of the animal. These tubes are not straight but coiled and give off numerous branches, at the termination of each of which is a peculiar cell with a vibratory process at its base called a **flame cell**; they are joined by a **transverse tube** at the anterior end of the animal. Portions of the excretory system can often be seen in the compressed animal, where they appear as fine lines.

Exercise 4. Draw an outline of the animal and place in it as much of the nervous and the excretory system as you have observed.

No special respiratory system is present in the Turbellaria, the ciliated outer surface of the body performing this function. A circulatory system and a blood fluid are also wanting. The branching of the digestive and excretory systems is correlated with this feature. Can you explain how? As in other flatworms, the turbellarians possess no body cavity, the primitive body cavity being filled secondarily by a peculiar vesicular connective tissue called **parenchyma.** The **muscular system** consists of a layer of strong circular and longitudinal muscles just beneath the surface of the body and of oblique muscles passing through the parenchyma.

CLASS: *Cestodes*

A TAPEWORM

Tapeworms are common parasites in the intestines of vertebrate animals. *Tænia saginata*, the common tapeworm infesting man, may often be obtained from physicians. If it is alive when obtained, it should be placed in a normal salt solution (a 0.75 per cent solution), in which it will keep alive for several hours, and may then be studied. If it is dead it should be preserved in alcohol or formalin. *Tænia serrata*, a tapeworm of the dog, and *Tænia crassicollis*, which lives in the cat, are both common animals and are convenient forms for study. The intestines of adult cats or dogs should be slit open and the worms taken out and placed alive in a normal salt solution. They are white, bandlike objects, six inches or more in length, which are attached by one end to the wall of the intestine. In separating them from the intestinal wall care should be taken not to tear them.

Study the movements and general form of the animals as they lie in the salt solution. The worm will be seen to be made up of a large number of segments, and to bear at the smaller end a small rounded knob. The segments are called **proglottids**, and the rounded knob, the **scolex**. The body of the animal is not made up of body divisions which we can call head and trunk. The scolex, however, may be held to represent its anterior end, the proglottids having arisen from it by a process of terminal growth. The scolex is thus the oldest part of the animal's body; in fact, it constitutes the entire parasite when it first arrives in the intestine of the host (as the animal is called in which a parasite lives), the proglottids only then beginning to grow. The youngest proglottids are those nearest the scolex; those at the opposite end of the body are the oldest and hence the largest. Count the proglottids. The animal attaches itself to the wall of the intestine by means of its scolex, which is provided for this purpose with four **suckers** and usually two rows of chitinous **hooks**; the scolex of *Tænia saginata* lacks the hooks. Thus attached, it lies immersed in the digestive fluids of its host and absorbs through the

outer surface of its body the nutriment it needs. It is without a digestive system.

Exercise 1. Draw an outline of the animal on a large scale, taking care to represent the number of proglottids accurately.

The Scolex. Cut off the scolex, mount it on a slide in glycerine or water, and examine it under the microscope. Notice the fine **excretory canals** which occur in every part of it. Can you determine their arrangement? Note the numerous minute **calcareous bodies.**

Exercise 2. Draw the scolex on a scale of 10. Represent accurately the suckers and the number and position of the hooks, if these are present.

Exercise 3. Draw a single hook highly magnified.

The Proglottids. Each proglottid is composed mainly of reproductive organs and circular, longitudinal, and oblique muscle fibers embedded in a spongy tissue called **parenchyma.** The parenchyma fills the entire primitive body cavity, which is thus absent in this animal. Each proglottid contains a complete set of both **male** and **female genital organs.** These are immature in the youngest and smallest proglottids; in those at about a third of the distance from the anterior end of the body they are mature; in the largest proglottids, those at the posterior end of the body, the **uterus** is so distended with eggs that most of the other genital organs are obliterated and do not appear. Two pairs of longitudinal **excretory canals** pass from one end of the worm to the other, running near to and parallel with each lateral edge; in each proglottid, also, are one or two **transverse canals.** One or more pairs of **longitudinal nerves** run parallel with and very near the excretory canals, which are also joined in each proglottid by a **ring commissure.**

Cut off two or three proglottids from the forward end of the body, two or three from about a third of the distance from the anterior end, and two or three from the posterior end, and soak them all first for a short time in a dilute solution of caustic potash and then in one of equal parts of glycerine and water.

Place the proglottids from the hinder end of the body in dilute glycerine between two glass slides, press them gently so as to

squeeze them as thin as possible without crushing them, and study them under the microscope. In the middle of one of the lateral edges of the proglottid notice a slight projection containing a depression. This is the **genital papilla**, and the depression is the **genital cloaca**. Two canals will be seen running from the genital cloaca toward the center of the proglottid. These are the **vasa deferens** and the **vagina**, the former being the larger of the two. The greater part of the proglottid will be seen to be occupied by a much-branched organ filled with a granular substance. This is the **uterus**, and the granules are eggs. Near each lateral edge of the proglottid will be seen a straight band. These two bands are the dorsal **excretory canals**; find the **transverse canal** near the hinder end of the proglottid. Between each canal and the edge of the proglottid will be seen a delicate line running parallel with the canal. These are the main **nerves**; they are joined by transverse nerves.

Exercise 4. Draw the proglottid, showing accurately all the features that you have observed.

Study in the same way the mature proglottids. Find the **uterus.** It is here a straight, narrow tube in the middle of the proglottid, and is not yet distended with eggs. Near the center and toward the posterior end of the proglottid will be seen an irregular mass of organs. These are the paired **ovaries**, two large, round bodies, one on each side of the uterus; the median **yolk gland**, which is below the end of the uterus, near the posterior margin of the proglottid; the **shell gland**, between the yolk gland and the uterus. From the shell gland the **vagina** and **vas deferens** proceed to the **genital cloaca**, the former being the smaller and more posterior of the two. Scattered throughout the proglottid are numerous small, round bodies, the **testes**, which are joined with the vas deferens by numerous minute **vasa efferentia**. Find the **excretory canals** and the **longitudinal nerves.**

Exercise 5. Draw the proglottid, showing all the features you have observed; carefully label all.

Study in the same way the immature proglottids.

Exercise 6. Draw the immature proglottid.

The tapeworm may fertilize itself or be fertilized by another individual, and where self-fertilization takes place one proglottid of the animal may fertilize another, or a single proglottid may fertilize itself. The ova from the ovaries, on being fertilized, pass at once into the uterus. The ripe proglottids, which are filled with eggs in which the embryo has already begun to develop, break off from the hinder end of the worm and pass out of the body of the host. They then break open or are crushed, and their eggs are scattered on all sides.

The Encysted Tapeworm. The adult worm alone is found in the intestine. The eggs, in order to develop, must pass out of the host and fall upon something which will afterward be eaten by another animal, called the **intermediate host**, which is itself preyed upon by the host. After being thus transferred to the stomach of the intermediate host, there hatches from each egg a minute, spherical embryo, called the **six-hooked embryo**, which is provided with three pairs of hooklike organs of locomotion. This embryo works its way through the wall of the intestine of the animal and migrates finally to some one of the internal organs, where it lodges and grows into a cystlike larval form, called the **cysticercus**. Within the cysticercus is a fully developed scolex, but turned wrong side out. If now the intermediate host is eaten by the host, the scolex turns right side out, passes into the intestine of the latter, attaches itself to the intestinal wall, and grows into an adult tapeworm.

The intermediate host of *Tænia saginata* is the beef, in the muscles of which the cysticercus will be found, if present. That of *Tænia serrata* is the rabbit and that of *Tænia crassicollis* is the mouse; in the former animal the cysticerci are embedded in the peritoneum or the liver, and in the latter, in the liver. Open the body cavity of either of these animals by a median ventral incision and look for cysticerci. They are large, whitish bodies and are easily detected if present. When a cysticercus is found, it should be carefully dissected out, its outer wall slit and the scolex exposed to view. Mount it on a slide in dilute glycerine and study it.

Exercise 7. Draw a view of the scolex in its cyst.

SUBPHYLUM BRYOZOA

BUGULA

Bugula turrita is a marine colonial bryozoan which is very common in the shallow waters along our coast. The colonies are a dull yellow in color and sessile, being attached to rocks, seaweed, and other objects. The animals are very small and must be studied with the aid of a microscope.

Study a large piece of a colony (alive if possible) and notice the spiral arrangement of the branches. A branch is made up of a double row of elongated partitions or chambers, each of which is called a **zoœcium.** Each zoœcium represents a separate individual of the colony; within its walls are the soft parts of the animal, which are called collectively the **polypide.** The individual bryozoan is thus made up of two distinct parts, the zoœcium and the polypide, the former constituting the chitinous outer wall of the animal, the latter comprising its viscera and the tentacles. At its upper, or distal, end the zoœcium has a large opening through which the forward end of the polypide can be protruded and into which it withdraws itself when alarmed. The **cuticula** which forms the zoœcium is rendered hard by the presence of carbonate of lime; it is thus much more enduring than the remainder of the animal, and after death the empty zoœcium may persist long after all the softer parts have disappeared. Look for the empty zoœcia in your specimen.

The different individuals of a colony have arisen by a process of budding from the individuals below them in the colony. Thus the oldest individuals are those nearest the base of the colony, the basal one being the progenitor of the entire colony. This is also the only individual of the colony which has not come into existence by a process of budding; it began its life as a free-swimming larva which was hatched from an egg.

The Zoœcium. Mount a small portion of the colony containing two or three branches on a slide under a cover glass.

Exercise 1. Draw a large and accurate outline of the zoœcia, leaving out the polypides. Observe very carefully the boundaries of the zoœcia and their relations to one another.

The Polypide. Study a number of polypides, both retracted and extended. The forward end of the polypide consists of a circular ridge, called the **lophophore**, which bears a row of long ciliated **tentacles**. In the midst of the circle is the **mouth**. The tentacles are vibratile and serve as respiratory as well as prehensile organs. It will be seen that the lophophore can be entirely withdrawn within the zoœcium.

The Digestive System. The **mouth** opens into the **pharynx**, which leads into the **œsophagus**. This opens into a large saclike **stomach**, the lower portion of which is lengthened into a long pouch. From the upper end of the stomach, near the base of the œsophagus, the short **intestine** leaves it and passes to the thick-walled **rectum**. This leads to the **anus**, which is situated just outside the lophophore near the mouth. The digestive tract has thus the shape of the letter V, the point of which is formed by the stomach pouch. Passing from the stomach pouch to the lower end of the body is a broad mesenteric strand called the **funiculus**. In order to study the digestive tract satisfactorily, a polypide should be found in which both arms of the V come into view.

The Muscular System. The retractor muscle, whose function it is to draw in the lophophore, may, in favorable specimens, be seen as a delicate strand which passes from the wall of the zoœcium to the pharynx.

The **nervous system** has not yet been observed in Bugula, but in nearly allied Bryozoa it consists of a single ganglion between the mouth and the anus. From it nerves radiate to the tentacles and other organs. There are no organs of special sense.

The Reproductive Organs. The animals are hermaphroditic. Ova develop from the peritoneal lining of the spacious body cavity and will be seen, when present, lying near the stomach pouch. Spermatozoa develop from the funiculus and, when present, form a mass around it; they fertilize the ova in the body cavity.

There are two methods of reproduction, the sexual, in which the new individual develops from the fertilized egg, and the asexual, in which the new individual arises by budding. As already stated, the entire colony, with the exception of its oldest member, has developed in the latter way.

Exercise 2. Draw an extended individual in which the entire digestive tract can be seen and label all the organs observed.

There are no special respiratory or excretory organs; the entire outer surface of the body performs these functions. The **circulatory system** is represented by the colorless blood fluid alone. There are no circulatory vessels, the blood being contained in the body cavity.

Avicularia and Oœcia. These are peculiar structures, found in connection with the zoœcia, which are morphologically equivalent to distinct individuals. An **avicularium** is a small structure, like a bird's head in shape (hence the name), which may be found attached to the wall of some of the zoœcia near the opening. It has a movable lower jaw which can be opened and shut by two sets of muscles. Its function is to seize and hold small animals. These soon die in its grasp, and their disintegrated remains are swept into the mouth by the ciliated tentacles. An **oœcium** is a disklike structure which, in some parts of the colony, lies in front of a zoœcium. It serves as an egg capsule in which the embryo develops. A single embryo will be found in each.

Exercise 3. Find a zoœcium with an avicularium attached and draw them.

Exercise 4. Find a zoœcium with an oœcium attached and draw them.

PHYLUM MOLLUSCA

Class: *Pelecypoda*

A FRESH-WATER CLAM (*ANODONTA* OR *UNIO*)

These animals are common in most parts of the country; they inhabit the sandy or gravelly bottoms of fresh-water streams and lakes. There are many species of fresh-water clams, two common genera being Anodonta and Unio, the former of which is characterized by the thinness of the shell and the latter by its thickness.

Study first the live animal, if possible. Its body is unsegmented and entirely inclosed in a bilateral, bivalve shell, which is the cuticula of the animal richly charged with calcareous salts. The two valves of the shell cover the right and left sides of the animal and are joined together on its dorsal side by the dark-colored **hinge ligament**, while their ventral edges are open; the animal is thus very much compressed laterally. The anterior end of the animal is more rounded and less elongated than the posterior end. Which is the right-hand valve? The elevation on each valve near the hinge toward the forward end is called the **umbo**. It is the oldest portion of the shell; from it as a beginning point the shell has grown in size by additions to its ventral edge. Note the parallel lines of growth. The ventral edges of the shell are thus the youngest portions of them.

Exercise 1. Make a drawing of the right-hand valve, indicating the anterior, posterior, dorsal, and ventral aspects, and showing the lines of growth.

Exercise 2. Make a drawing of the dorsal aspect of the animal.

Kill the animal by immersing it for a few minutes in hot water (70° C.). As the shell is kept closed by the contraction of the two muscles which pass between its valves, it will gape open as soon as

the animal is dead and the muscles are relaxed. It is the elasticity of the hinge ligament which causes it to open.[1]

Examine the animal as it lies in the shell. It will be seen that the inner surface of each valve is covered with a soft, slimy membrane, the lower edge of which is parallel to the edge of the shell. This is the **mantle**; it is a double fold of the dorsal integument of the body, one side of the body being covered by either fold. The mantle is the matrix of the shell; that is, it secretes the shell. Its lower edge is provided with muscle fibers and can be extended beyond the edge of the shell; it also possesses sensory functions.

Observe the large, soft **visceral mass** hanging between the two lobes of the mantle; it contains the viscera of the animal. On the lower side of the visceral mass, that is, toward the gape of the shell, is the muscular **foot**, which can be extended below the edge of the shell and is the organ of locomotion. Observe the two leaf-like **gills** on each side of the visceral mass and foot; notice also the two large **adductor muscles**, one in front of and the other behind the visceral mass, which pass from one valve of the shell to the other and serve to close them.

Pass a knife between the mantle and the left shell and separate them from each other. Cut the two muscles close to the shell; cut the elastic hinge ligament and remove the left shell.

Study the inner surface of the shell. Note the two large scars marking the surfaces of attachment of the adductor muscles; just above each is the scar of a much smaller muscle, the **retractor** of the foot, and just posterior to the anterior adductor muscle is the scar of the **protractor** muscle of the foot. Note the broad line which joins the scars, running parallel with the edge of the shell. This is the **pallial line**; it is formed by the insertion in the shell of the delicate muscle fibers at the edge of the mantle. Do you find **hinge teeth** in the shell just beneath the hinge ligament? **Unio** has such teeth; **Anodonta** is without them and is also characterized by the thinness of its shell.

[1] The shell may also be opened by inserting some sharp, wedge-shaped instrument between its valves. The valves are thus pressed apart far enough to admit the blade of a scalpel, by means of which the adductor muscles should be cut close to the left valve of the shell. The hinge ligament should then be cut and the left valve be removed.

Exercise 3. Draw a view of the inner surface of the shell.

Break the shell and examine the broken edge with a hand lens. Study the structure of the shell. It is composed of three layers: the inner **mother-of-pearl layer** (which is secreted by the entire surface of the mantle), the **prismatic layer**, and the **organic layer** or **periostracum** on the outside. The two latter layers are secreted by the edge of the mantle; the periostracum is very thin and easily peeled off. Place a piece of the shell in a solution of hydrochloric acid; note the effervescence which results; note also that an organic remnant, even of the two inner layers, is left.

Exercise 4. Draw a view of the broken edge of the shell on a scale of 5. Show the prisms of the prismatic layer.

Place the animal in water and study it as it lies in the right shell.[1] The two halves of the mantle will be seen to envelop entirely the visceral mass and the foot. Over the entire dorsal portion of the visceral mass the mantle is fused with it and cannot be separated, but the lateral and ventral portions of the mantle lobes hang free, inclosing an extensive space, which is called the **mantle cavity**. In it, on each side of the visceral mass, lie the two leaflike **gills**. In front of the gills are two pairs of triangular flaps, the **oral palps**, between which, in the median line and just back of the anterior adductor muscle, lies the **mouth**. Find it.

Trace the irregular line of attachment of the mantle with the visceral mass; it follows the base of the gills and of the oral palps and passes beneath both adductor muscles. Observe the edges of the mantle and note that at the hinder end of the animal they are darkly pigmented, and the middle point of the pigmented line is joined with the base of the gills by a short **septum**. This septum divides the posterior portion of the mantle cavity into a **dorsal** and a **ventral chamber**. The latter is the very large **branchial chamber** which contains the gills; the former is the very small **cloacal chamber**. Identify these chambers. The pigmented edges of the mantle are at this place modified so as to form, when the edges of the two sides of the mantle are applied

[1] For the study of the soft parts of the clam it is well to have at hand also a specimen which has been deprived of both valves of the shell.

to each other, two short tubular openings, which place these two chambers in communication with the outside water and are called the **siphons**. The ventral siphon is called the **branchial** or **incurrent siphon**; through it water streams into the branchial chamber bearing food and air for respiration. The dorsal siphon is called the **excurrent** or **cloacal siphon**, and through it water passes outward charged with fecal matter from the alimentary tract and carbon dioxide of respiration. Note the sensory tentacles on the branchial siphon.

Probe the dorsal siphon. Carefully remove the left lobe of the mantle after cutting it with fine scissors along its line of attachment with the visceral mass.

Through the transparent body wall observe the organs in the dorsal portion of the visceral mass. Just back of the anterior adductor muscle is the **liver**, which can often be recognized by its greenish color. Between the hinge ligament and the base of the gills lies the **heart** in its transparent **pericardium**, and beneath it is the dark-colored **kidney**. The **rectum** may be seen passing through the pericardium and the heart, then extending above the posterior adductor muscle to the **cloaca**, where it ends with the **anus**. Cut open the cloacal chamber by a slit in the side of its siphon. Find the hinder end of the rectum and the anus. Note just beneath the muscle a canal which accompanies the base of the gill forward. This is the **suprabranchial passage** of the outer gill; it runs posteriorly to the cloacal chamber. Blow into it with a blowpipe, also probe it from behind.

Exercise 5. Draw a semidiagrammatic view of the animal lying in the right-hand valve of the shell, representing the organs above mentioned. Carefully label all.

The Respiratory System. The gills have already been noticed. The two gills on each side of the visceral mass are in origin but a single organ, which is called the **ctenidium**. The clam is thus provided with a single pair of ctenidia, which are homologous to those of the squid and of snails. Each gill consists of a pair of plates, or lamellæ, united at their lower edges and open above, and further joined by vertical or dorsoventral cross

partitions, the **interlamellar partitions**. The space between the lamellæ is thus divided into parallel, vertical chambers, the **water tubes**, which run from the bottom to the top of the gill and open above into the **suprabranchial passage**. One of these passages runs along the base of each gill, as a wide canal, to the cloacal chamber. We have already observed the suprabranchial passage of the outer gill. In order to observe that of the inner gill, lift up both gills; the inner lamella of the inner gill will, in most species of clam, be seen not to be united with the wall of the visceral mass along the hinder portion of the foot, but to have a free edge. The long slitlike opening thus presented leads into the inner suprabranchial passage. Probe it backward to the cloacal chamber. Probe it also from the hinder end forward and notice that back of the visceral mass the two inner suprabranchial passages — that is, those belonging to the inner gills of the right and left sides — coalesce, forming a single passage.

Study the finer structure of the gills. Place a gill on a glass slide in a little water and with forceps and a knife carefully separate the two lamellæ. Mount a piece of a lamella in water and study it under a compound microscope. Note the vertical interlamellar partitions. Observe that the lamella is a delicate latticework made up of ridges, the **gill filaments**, running vertically and thus parallel with the interlamellar partitions, and of cross ridges, the **interfilamentary connections**, which run between and connect the vertical filaments. The apertures in the latticework place the water tubes in communication with the water in the branchial chamber. The gill filaments are provided with cilia, the action of which causes streams of water to pass into the water tubes. The cilia may easily be seen by mounting a piece of a gill of a freshly killed animal on a slide and examining it under a compound microscope. The course of the respiratory water is from the branchial chamber into the water tubes, through which it passes into the suprabranchial passages and through these into the cloacal chamber.

The outer gill and sometimes the inner gill also act as a brood chamber in the female clam, and during the breeding season will be found to be distended with eggs, or embryos.

Exercise 6. Draw a diagram of the respiratory system showing the gills and their relation to the suprabranchial passages. Show the direction of the flow of the respiratory water by means of arrows.

Exercise 7. Draw a diagram showing the minute structure of a lamella.

The Circulatory System. With fine scissors and great care cut open the **pericardium** by a slit along its dorsal border. Note the **heart**, with the rectum passing through it. The heart consists of three chambers: a median, thick-walled **ventricle** and two lateral **auricles.** These latter are delicate, thin-walled organs, triangular in shape, the base of the triangle lying along the dorsal border of the gills and the apex communicating with the ventricle. If the left auricle has been injured in the dissection, the right one is easily seen by looking across the pericardial space. From the ventricle an anterior and a posterior artery pass to either end of the body. These arteries lie alongside the rectum, to which the anterior one is dorsal and the posterior one is ventral; they are difficult to distinguish from it, except in specimens in which the heart has been injected.

The course of the blood is the following: by the contraction of the heart the blood is sent to all parts of the body; on its return course it is first conveyed through a system of lacunæ to the kidneys, and thence to the gills; here it circulates in vessels which run through the interlamellar partitions, the gill filaments, and the interfilamentary connections, and is oxygenated; it then passes into the auricles.

The Excretory System. This system consists of a pair of **kidneys,** which are dark-colored organs lying just beneath the pericardium and in front of the posterior adductor muscle. Each kidney consists of two parts, the **kidney proper** and the **ureter.** The former is a dark, thick-walled gland which lies beneath the ureter and communicates with it at its hinder end. The ureter is a thin-walled vessel lying above the kidney proper, with a small external opening on the side of the visceral mass beneath the anterior end of the kidney and near the base of the inner gill. It is usually difficult to find but may be recognized by its white lips. The kidney also possesses at its anterior end a duct lead-

ing into the pericardial cavity. Slit open the ureter and kidney proper in clean water and observe their inner structure.

Exercise 8. Draw a diagram representing the pericardial cavity and the kidney, showing the relation of the two structures to each other. Draw the heart in the pericardial cavity, showing the relation of the auricle to the gills.

The Digestive System. The stomach and intestine are embedded in the visceral mass and are difficult to dissect out of it. With care and patience, however, it can be done. Find the **mouth** between the two pairs of palps; note the upper and the lower **lips**, which connect the upper and the lower pairs of palps respectively. The mouth is seen to the greatest advantage in a specimen which has been deprived of both valves of the shell. Trace the rectum from the anus to the place of its entrance into the visceral mass. Carefully remove with forceps and knife the tough white integument which covers the left side of the visceral mass, taking care not to disturb the organs beneath. The soft cream-colored mass just above the foot is the reproductive gland; the light-greenish mass lying just above this is the **liver**. Embedded in these masses lies the **alimentary tract**, a narrow, delicate tube, which will be injured in the dissection unless the greatest care is taken. Gently scrape away the soft mass which surrounds the alimentary tract, laying it entirely bare. The water in the dissecting pan must be frequently renewed to keep it clear, and great care must be taken not to break the tract. The course of the whole digestive tract is the following: The mouth opens into the short **œsophagus**, after which the canal dilates to form the **stomach**. The dark-colored liver surrounds the stomach. Back of the stomach is the **intestine**, a narrow tube which runs backward and downward to the hinder end of the visceral mass; it then turns upward and runs forward to a point above the stomach, where it turns downward to the lower side of the visceral mass; it then bends dorsally again and runs to the point where it leaves the visceral mass. Here the **rectum** begins and passes through the heart and above the posterior adductor muscle to the **anus** in the cloacal chamber.

Clams feed upon minute organisms and organic particles contained in the water. Some of the water in the mantle cavity is drawn by the ciliated oral palps into the mouth and passes through the alimentary tract, where organic substances contained in it are digested and absorbed. The clam usually lies with its forward end buried in the sand and its hinder end with the siphons projecting into the water.

Exercise 9. Draw a diagrammatic view of the digestive system.

The Reproductive System. The sexes are separate. The **reproductive glands** (testes or ovaries) are very similar to each other and consist of a pair of cream-colored masses which fill a large part of the visceral mass. They communicate with the outside through a pair of minute openings, one on each side of the visceral mass near the base of the gills. The opening can often be located by pressing out from them eggs or sperm. The eggs, as soon as laid, pass into the water tubes of the outer gills of the mother, where they hatch. The young larvæ are very immature and are called **glochidia**; they leave the mother and attach themselves to the sides of fishes by means of a pair of sharp projections on the ventral edges of the valves of the shell, where they lead a parasitic life. While here they undergo a metamorphosis and finally attain the adult structure, when they detach themselves and drop to the bottom. Look for glochidia in your specimen.

The Nervous System. This consists of three pairs of ganglia: the **cerebral ganglia**, or **brain**, the **pedal ganglia**, and the **visceral ganglia**, and the nerves proceeding from them. Each of the last two pairs is joined with the brain by a pair of nerve connectives.

First find the visceral ganglia. They are a small grayish or pinkish mass on the ventral surface of the posterior adductor muscle with nerves radiating in all directions. Two of these nerves, the **cerebrovisceral connectives**, will be seen passing forward, one on each side of the visceral mass.

Next find the brain. It consists of a pair of ganglia situated above the mouth, just behind the anterior adductor muscle. The two ganglia are not so close together as those of the visceral pair; they lie on either side of the muscle and are united by a com-

missure. Each ganglion sends out three large nerves: the **cerebrovisceral connective**, which goes to the visceral ganglia, the **cerebropedal connective**, which goes to the pedal ganglia, and the **pallial nerve**, which passes to the mantle. Find them.

The pedal ganglia form a nervous mass buried in the foot near its base. Make a shallow longitudinal incision in the bottom of the foot and gently pull the flaps apart; the pinkish mass and the nerves radiating from it will be seen.

Exercise 10. Draw a diagram representing the nervous system.

Make several transverse sections with a razor through the region of the heart of a clam which has been previously hardened. Identify all the organs which appear.

Exercise 11. Draw a diagram representing a cross section; carefully label all the organs.

CLASS: *Pelecypoda*

THE OYSTER

Select a large, live oyster in the shell, and if it is dirty wash it thoroughly. The shell is sometimes covered with mud, and with hydroids, sponges, tube-forming annelids, and other marine animals. The small, round holes made by the yellow boring sponge are often conspicuous.

The two valves of the shell will be seen to be different in shape, one being more or less flattened and the other much deeper and more convex. These two valves cover the right and left sides of the animal's body, the convex valve being on the left and the flattened one on the right side. The oyster is a sessile animal, after it has passed through its youthful migratory period, and is fastened to a rock or shell or other stationary object by its left shell. It thus lies on its left side, and the flat right shell acts as a cover which can be raised to allow the animal to draw in water containing food and respiratory air, and closed when danger threatens. The very young oyster is a symmetrical animal which swims about actively in the water. While it is still very small — so small, in fact, that it is barely visible to the naked eye — it settles down and fastens itself to some stationary object, and in its subsequent growth accommodates itself more or less to the irregularities of this substratum. This is the reason why the shell is so often rough and irregular in shape.

The smaller end of the shell is the anterior end. The **hinge ligament** is situated here, the elasticity of which keeps the shell open except when it is closed by the contraction of the large adductor muscle. At this end is also the **umbo**, the oldest part of the shell. Note the parallel lines of growth which extend from the umbo to the ventral and posterior sides of the shell. When the anterior, the right, and the left sides of the shell are known, the ventral and posterior sides can be easily determined.

Exercise 1. Make an outline drawing of the right valve, indicating the anterior, posterior, dorsal, and ventral aspects and showing the lines of growth.

Remove the right valve in the following way: Break off the edge of the shell with a hammer, insert the blade of a scalpel and cut the large adductor muscle, which is not far from the edge but nearer the dorsal than the ventral margin. It is important to keep the blade close to the right valve so as not to mutilate the internal organs. Force off the right valve and examine its inner surface.

Exercise 2. Draw the inner surface of the shell, showing the muscle scar with its lines of growth and the hinge ligament, and label the dorsal, ventral, anterior, and posterior sides of it.

Study the animal as it lies in the left valve. Note the soft, shiny **mantle**, which covers the inner surface of the shell and has secreted it. The mantle is a double fold of the integument which extends ventrally from the dorsal side and covers the two lateral sides of the body. Its lower edge is bordered by a fringe of short, pigmented **tentacles**, which are the principal sense organs of the animal; it is also provided with muscle fibers which enable it to be slightly extended beyond the edge of the shell.

The most conspicuous organ in the body will be seen to be the large **adductor muscle**. Lying between it and the hinge ligament is the **visceral mass**, containing most of the viscera. Along the ventral side are the four **gills**.

Put the oyster into a pan of water and with fine scissors and forceps remove the right mantle. Just in front of the adductor muscle observe the **pericardium**. Carefully cut it away and see the **heart**, which lies in the pericardial cavity; it will be beating if the animal is still alive. The **ventricle** is dorsal in position; the **auricle** is ventral, lying next to the gills, from which it receives the purified blood. The four gills lie close together, no foot being present to separate the two right-hand from the two left-hand gills. Just in front of the gills, at the front end of the body, are the two pairs of large **oral palps**. The **mouth** is between these palps, two being on each side of it. Find the mouth and note that it lies between an **under** and a **lower lip**, each of which is formed by the union of a pair of palps; that is, a palp on the right side joins one on the left and forms the upper lip, and the other two palps join to form the lower lip.

Oysters feed on minute organisms contained in the water. These are caught in the slime which exudes from the surface of the gills and moved forward by the action of the cilia of the gills and the palps to the mouth.

The **anus** and the **rectum** will be seen on the dorsal side of the adductor muscle.

Exercise 3. Make a drawing of the oyster as it lies in the left shell, representing all the organs above mentioned. Carefully label all.

The Digestive Tract. This consists of the short **œsophagus**, the **stomach** and the dark-colored **liver** which surrounds it, and the long **intestine**. The mouth opens directly into the œsophagus, which leads to the stomach. The position of this organ can easily be determined, because it is embedded in the dark-brown liver. Carefully scrape or cut away the side of the visceral mass and expose the liver; continue the process until the stomach is seen. The intestine extends straight back from the stomach to a position ventral to the adductor muscle and between it and the gills. It then turns on itself and passes straight forward to the dorsal side of the stomach, around the forward and ventral sides of it, and thus back again to the dorsal side of the muscle, where it ends with the anus. Most of it is surrounded by the yellow **reproductive gland**. Lay bare the intestine. This can be done best after the oyster has been hardened for a few days in a 5 per cent solution of formalin.

Exercise 4. Make a drawing of the digestive tract in an outline of the animal's body.

The remaining systems of organs of the visceral mass will not be studied in this dissection.

The American oyster is a unisexual animal; the common European oyster is hermaphroditic. The reproductive glands, the **ovaries** or **testes**, are a pair of yellowish or whitish organs of irregular form which occupy the larger part of the visceral mass and surround the digestive tract and other organs. The **kidneys** are also a pair of organs of irregular form which, together with a portion of the intestine, occupy the lower and hinder part of the

visceral mass, between the muscle and the gills. The **nervous system** has been much modified by the sessile habit of life of the oyster. The cerebral ganglia are represented by a nerve ring which surrounds the mouth; it is called the **circumpallial nerve**. Fibers from this ring go to the pigmented sense papillæ at the margin of the mantle. The **visceral ganglia** lie along the antero-ventral side of the muscle and are joined with the cerebral ring by **longitudinal connectives**. The pedal ganglia are wanting.

CLASS: *Pelecypoda*

THE HARD-SHELL CLAM (*VENUS MERCENARIA*)

This is a very common marine mollusk which inhabits the sandy bottoms of the ocean along the Atlantic coast. The soft-shell clam (*Mya arenaria*), which lives in mud flats visible between tides, resembles it very much in structure and may be used for this dissection.

Study the live animal first, if possible. Its body is unsegmented and is entirely inclosed in a bilateral, bivalve shell, which is the cuticula of the animal richly charged with calcareous salts. The two valves of the shell cover the right and left sides of the animal and are joined together on its dorsal side by the dark-colored **hinge ligament**, while their ventral edges are open; the animal is thus very much compressed laterally. The anterior end of the animal is truncated; the posterior end is elongated. Which is the right-hand valve? The elevation on each valve near the hinge ligament is called the **umbo**. It is the oldest portion of the shell; from it as a beginning point the shell has grown in size to its present proportions by additions to its ventral edge. Note the parallel lines of growth. The ventral edges of the shell are thus the youngest portions of them.

Exercise 1. Make a drawing of the right-hand valve, indicating the anterior, posterior, dorsal, and ventral aspects, and showing the lines of growth.

Exercise 2. Make a drawing of the dorsal aspect of the animal.

Kill the animal by immersing it for a few minutes in hot water (70° C.). Since the shell is kept closed by the contraction of the two muscles which pass between the valves, it will gape open as soon as the animal is dead and the muscles are relaxed. It is the elasticity of the hinge ligament which causes it to open.[1]

[1] The shell may also be opened by inserting a sharp, wedge-shaped instrument between the valves. The valves are thus pressed apart far enough to admit the blade of a scalpel, by means of which the adductor muscles should be cut close to the left valve of the shell. The hinge ligament should then be cut and the left valve removed.

Examine the animal as it lies in the shell. It will be seen that the inner surface of each valve is covered with a soft, slimy membrane, whose lower edge is parallel with the edge of the shell. This is the **mantle**; it is a double fold of the dorsal integument of the body, one side of which is covered by either fold. The mantle is the matrix of the shell; that is, it secretes it. The lower edge of the mantle is provided with muscle fibers and can be extended beyond the edge of the shell; it also possesses sensory functions; in some pelecypods eyes are situated in the mantle's edge.

Observe the large, soft **visceral mass** hanging between the two lobes of the mantle; it contains most of the viscera of the animal. On the lower side of the visceral mass, that is, toward the gape of the shell, is the muscular, wedge-shaped **foot**, which can be extended beneath the edge of the shell and is the organ of locomotion. Notice the two leaflike **gills** on each side of the visceral mass and foot. Observe the two large **adductor muscles**, one in front of and the other behind the visceral mass, which pass from one valve to the other and serve to close them.

Pass a knife between the mantle and the left shell and separate them from each other. Cut the two muscles close to the shell; cut the hinge ligament and remove the left shell.

Study the inner surface of the shell. Note the two large scars marking the surfaces of attachment of the adductor muscles; just above the anterior scar is that of a much smaller muscle, the anterior **retractor** of the foot. Note the broad line which joins the scars and runs parallel with the edge of the shell except near the posterior muscle scar, where it bends forward, forming a triangular indentation. This is the **pallial line**; it is formed by the insertion in the shell of the delicate muscle fibers near the edge of the mantle. The indentation is the **pallial sinus**. Note the hinge teeth just beneath the umbo.

Exercise 3. Draw a view of the inner surface of the shell.

Break the shell and examine the broken edge with a hand lens. Study the structure of the shell. It is composed of three layers: the inner **mother-of-pearl layer**, which is secreted by the entire surface of the mantle, the **prismatic layer**, and the **organic layer**, or

periostracum, on the outside. The two latter layers are secreted by the edge of the mantle; the periostracum is very thin and is frequently wanting on some portions of the shell. Place a piece of the shell in a solution of hydrochloric acid; note the effervescence which results.

Exercise 4. Draw a view of the broken edge of the shell on a scale of 5. Show the prisms of the prismatic layer.

Place the animal in water and study it as it lies in the right shell.[1] The two halves of the mantle will be seen to envelop entirely the visceral mass of the foot. Over the dorsal portion of the visceral mass the mantle is fused with it and cannot be separated, but the lateral and the ventral portions of the mantle lobes hang free, inclosing an extensive space, which is called the **mantle cavity**. In this cavity, on each side of the visceral mass, lie the two leaflike **gills**. Observe the edges of the mantle. They are fused forward of the anterior adductor muscle; the entire ventral edges are free and permit the foot to protrude between them; their posterior edges are richly pigmented, and are also fused and modified to form the two **siphons**. These are tubes which can be extended beyond the shells and through which water is taken into and expelled from the mantle cavity. Probe them. Note on each side below the posterior adductor muscle the triangular muscle which connects the siphons with the shell. It is the **siphonal retractor muscle**. Between the two siphons in the mantle cavity note the short, transverse **septum** which divides the posterior portion of the mantle cavity into two chambers, a **dorsal** and a **ventral** one. The latter is the very large **branchial chamber**, which contains the visceral mass and the gills; the former is the very small **cloacal chamber**. The ventral siphon is called the **branchial** or **incurrent siphon**; through it the water streams into the branchial chamber, bearing food and air for respiration. The dorsal siphon is called the **excurrent** or **cloacal siphon**, and through it water passes outward from the cloacal chamber, charged with carbon dioxide of respiration and with fecal matter from the alimentary tract. Probe the cloacal chamber.

[1] For the study of the soft parts of the clam it is well to have also at hand a specimen which has been deprived of both valves of the shell.

Carefully remove the left mantle lobe after cutting it with fine scissors at its line of attachment, beginning at the forward end. Cut off the siphonal muscle, leaving the siphons in position. Place the animal in water and study the arrangement of the organs. Observe the position of the **gills**; note in front of them two triangular flaps, the **oral palps**; in the median line between the two pairs of oral palps is the **mouth**; find it. Along the base of the gills note an elongated passage leading posteriorly to the cloacal chamber; this is the **suprabranchial passage** of the outer gill. Blow into this passage at its hinder end in the cloacal chamber with a blowpipe, or probe it.

Observe again the siphonal region. Note again the short septum which separates the branchial from the cloacal chamber, and the opening between it and the visceral mass; probe this opening. Just beneath the umbo will be seen through the semitransparent body wall a dark-colored mass, the **liver**, back of which are the yellowish **reproductive gland** and the dark-colored **organ of Keber**. Back of the latter is the **pericardium**, within which is the **heart**. Beneath the heart and in front of the posterior adductor muscle is the dark-colored **kidney**. Passing through the pericardium and the heart and above the posterior adductor muscle to the cloaca will be seen the **rectum**. It ends with the **anus** near the hinder surface of the muscle. Open the cloacal chamber by a slit in the side of its siphon and find the anus.

Exercise 5. Draw a semidiagrammatic view of the animal lying in the right-hand valve of the shell, representing the organs above mentioned. Carefully label all.

The Respiratory System. The gills have already been noticed. The two gills on each side are in origin but a single organ, which is called the **ctenidium**. The clam is thus provided with a single pair of ctenidia, which are homologous to those of the squid and of snails. Each gill consists of a pair of plates, or lamellæ, united at their lower edges and open above, and further joined by vertical or dorsoventral cross partitions, the **interlamellar partitions**. The space between the lamellæ is thus divided into parallel, vertical chambers, the **water tubes**, which run from the

bottom to the top of the gill and open above into the **suprabranchial passage**. This is a wide canal running along the base of each gill to the cloacal chamber. The course of the suprabranchial passage of the outer gill has already been noted. In order to observe that of the inner gill, lift up both gills; the inner suprabranchial passage will be seen at the base of the inner gill. Probe from the cloacal chamber into it. Notice that back of the visceral mass the two inner suprabranchial passages coalesce and form a single passage.

Study the finer structure of the gills. Place a gill on a glass slide in a little water and with forceps and knife carefully separate the lamellæ. Mount a piece of a lamella in water and study it under a compound microscope. Note the vertical interlamellar partitions. Observe that the lamella is a delicate latticework made up of ridges, the **gill filaments**, which run vertically and thus parallel with the interlamellar partitions, and of cross ridges, the **interfilamentary connections**, which run between and connect the vertical filaments. The apertures in the latticework place the water tubes in communication with the water of the branchial chamber. The gill filaments are provided with cilia, as may easily be seen if the gill is alive, the action of which causes streams of water to pass into the water tubes. The course of the respiratory water is from the branchial chamber into the water tubes, through which it passes to the suprabranchial passages, and through these into the cloacal chamber, whence it is ejected through the cloacal siphon.

Exercise 6. Draw a diagram of the respiratory system, showing the gills and their relation to the suprabranchial passages. Show the direction of the flow of the respiratory water by means of arrows.

Exercise 7. Draw a diagram showing the structure of a lamella.

The Circulatory System. With fine scissors carefully cut open the pericardium by a slit along its dorsal border and expose the **heart**. Note the heart, with the rectum passing through it. The heart consists of three chambers; a median, thick-walled **ventricle** and two lateral **auricles**. These latter are delicate, thin-walled organs, triangular in shape, the base of the triangle lying

along the dorsal border of the gills and the apex communicating with the ventricle. If the left auricle has been injured in the dissection, the right one is easily seen by looking across the pericardial space. From the ventricle an interior and a posterior artery pass to either end of the body. The posterior artery expands, near the posterior end of the pericardium, to form a large, thick-walled sac, the **arterial bulb**. These two arteries lie alongside the rectum, to which the anterior one is dorsal and the posterior one is ventral; they are difficult to distinguish from it, except in specimens in which the heart has been injected.

The course of the blood is the following: by the contraction of the heart the blood is sent to all parts of the body, whence it is conveyed through a system of lacunæ to the kidneys and thence to the gills; here it circulates in vessels which run through the interlamellar partitions, the gill filaments, and the interfilamentary connections, and is purified; it then passes into the auricles.

The Excretory System. This consists of a pair of **kidneys** which lie just beneath the pericardium and in front of the posterior adductor muscle. Each kidney consists of two parts, the **kidney proper** and the **ureter**. The former is a dark, thick-walled gland which lies beneath the ureter and communicates with it at its hinder end. The ureter is a thin-walled vessel lying above the kidney proper, with a small external opening in the side of the visceral mass near the base of the inner gill which is usually difficult to find. The kidney also possesses at its anterior end a duct leading into the pericardial cavity. Slit open the ureter and kidney proper and observe their inner structure.

Exercise 8. Draw a diagram representing the pericardial cavity and the kidney, showing the relation of the two structures to each other. Draw the heart in the pericardial cavity, showing the relation of the auricle to the gills.

The Digestive System. The stomach and intestine are embedded in the visceral mass and are difficult to dissect out of it. With care and patience, however, it can be done. Find the **mouth** between its two pairs of palps; note the **upper** and the **lower lips**, which connect the upper and the lower pair of palps respectively. The mouth is seen to the greatest advantage

in a specimen which has been taken out of both shells. Trace the rectum from the anus through the heart to the point where it meets the visceral mass. With forceps and knife carefully remove the tough white integument which covers the left side of the visceral mass. The soft, cream-colored mass filling the greater part of it is the reproductive gland; the greenish mass above is the liver. Embedded in these masses lies the **alimentary tract**, a narrow, delicate tube, which will be injured in the dissection unless the greatest care is taken. Gently scrape away the soft mass which surrounds the alimentary tract, laying it entirely bare. The water in the dissecting pan must be frequently renewed to keep it clear, and great care taken not to break the canal. The course of the whole digestive tract is the following: The mouth opens into the short **œsophagus**, after which the canal dilates to form the **stomach**. The liver surrounds the stomach and is connected with it by several ducts. Back of the stomach is the **intestine**, which first runs backward and downward to the posterior part of the visceral mass, after several turnings in the lower part of which it bends upward and runs forward parallel with the posterior margin of the visceral mass to its dorsal border, where it leaves it. Here the **rectum** begins and passes through the heart and above the posterior adductor muscle to the **anus**. A small, transparent rod is often present in the intestine; its function is unknown.

Clams feed upon minute organisms and organic particles contained in the water. Some of the water in the mantle cavity is drawn into the mouth by the ciliated oral palps and passes through the alimentary tract, where the organic substances are digested and absorbed.

Exercise 9. Draw a diagrammatic view of the digestive system.

The Reproductive System. The sexes are separate. The **reproductive glands** (testes or ovaries) are very similar to each other and consist of a pair of cream-colored masses which fill a large part of the visceral mass. Their external openings are a pair of minute pores, one on each side of the visceral mass just below and in front of the opening of the ureter. They can sometimes be located by pressing out from them eggs or sperm.

The **nervous system** consists of three pairs of ganglia: the **cerebral ganglia**, or **brain**, the **pedal ganglia**, and the **visceral ganglia**, and the nerves proceeding from them. Each of the last two pairs is joined with the brain by a pair of nerve connectives.

First find the visceral ganglia. They are a small, pinkish mass on the ventral surface of the posterior adductor muscle, with nerves radiating in all directions. Two of these nerves, the **cerebrovisceral connectives**, will be seen passing forward, one on each side of the visceral mass.

Next find the brain. It consists of a pair of pinkish ganglia situated above the mouth, just behind the anterior adductor muscle. The two ganglia are not so close together as are those of the visceral pair; they lie on each side of the muscle and are united by a commissure. Each ganglion sends out three large nerves: the **cerebrovisceral connective**, which goes to the visceral ganglia, the **cerebropedal connective**, which goes to the pedal ganglia, and the **pallial nerve**, which passes to the mantle. Find these nerves.

The pedal ganglia form a nervous mass buried in the foot near its base. They must be sought by cutting into the foot near its base and may be recognized by their pink color.

Exercise 10. Draw a diagram representing the nervous system.

Make several transverse sections with a razor through the region of the heart of a clam which has been previously hardened. Identify all the organs which appear.

Exercise 11. Draw a diagram representing a cross section; carefully label all the organs.

CLASS: *Gastropoda*. ORDER: *Pulmonata*

A LAND SNAIL

The edible French snail (*Helix pomatia*) is very common in Europe, in many parts of which it is used for food. It is imported into this country for the same purpose and may be obtained at small cost in New York and other cities. It is especially adapted for dissection, but any large Helix may be used instead. The large slug (*Limax maxima*) is very similar to Helix in structure and may also be used, but as it has no coiled shell, that feature of the dissection would be omitted.

The snail is a terrestrial animal and feeds principally upon leaves. It hibernates in the winter under stones and logs, after having first closed the mouth of its shell with a thin disk of hardened, calcified slime called the **epiphragma**. If it is still in winter quarters when obtained, the epiphragma should be removed and the animal placed among fresh leaves in a warm room, when it will soon come out of its shell and begin to feed. Snails are best killed for dissection by drowning. They should be placed in a large, covered jar of water, when they will die extended in from one to two days. If the air is first boiled out of the water, the process will be accelerated, but the animal should not be placed in water which is still hot.

Study the external characters of the animal. Its body is unsegmented and is covered with a shell, but unlike the shell of the pelecypod that of the snail is a univalve. As in other mollusks, the shell is the cuticula of the animal charged with calcareous salts, and forms an exoskeleton. In shape the shell is an elongated cone which has been twisted to the right, forming a closely coiled spiral. The tip of the spiral is called the **apex**, the opening is called the **mouth**, and its axis. the **columella**. How many turns does the spiral make? The apex corresponds to the umbo of the pelecypod; it is the oldest portion of the shell, the point from which its growth has proceeded. Note the parallel lines of growth. The ventral edge, or mouth, of the shell is thus its youngest part. The animal can withdraw its entire body within

the shell, but when it is walking or feeding it protrudes its **head** and **foot**. The **visceral mass**, containing all its viscera, is always covered by the shell and has thus its exact shape; that is, it is an elongated cone which has suffered a dextral twisting so as to form a closely coiled spiral. As a matter of fact, however, it is the visceral mass which has been primarily twisted; the shell is twisted because it covers the visceral mass. If the spiral were to be imagined uncoiled and extending straight up above the foot, the apex would be the uppermost and the foot the lowermost portion of the body; the apex is thus, morphologically, the dorsal and the foot is the ventral aspect of the animal.

As in the pelecypod, the visceral mass is inclosed in a **mantle**, which is a fold of the dorsal integument, but unlike the pelecypod it is a single fold and not a double one. This fold falls about and covers the visceral mass on all sides, as does a thimble the finger it is on, and secretes the shell on its outer surface. The ventral edge of the mantle is provided with muscles, so that it can be protruded beyond the mouth of the shell or retracted within it. This edge is called the **collar**. Find it in your specimen. On the right side of the animal note the deep notch and the round hole in the collar. This is the **respiratory pore**, which opens into the **respiratory chamber**. This chamber is the **mantle cavity**. Probe it gently and determine its extent. The animal being terrestrial has no gills, but respires by means of a **lung**, which is a highly vascularized portion of the wall of the mantle cavity. In a live animal note its power to open and close the respiratory opening.

The **foot** of the animal forms a broad creeping disk, adapted for locomotion on flat surfaces. Its wavelike undulations may be observed by causing the animal to walk over a glass plate. The **head**, which is wanting in the pelecypods, forms the anterior end of the animal and bears two pairs of hollow, retractile **tentacles**, the posterior pair carrying each an **eye** at its extremity. The **mouth** of the animal is between and a little below the base of the anterior pair of tentacles. Probe it and note the paired, lobed **lips**. Just beneath the mouth is the broad opening of the **pedal slime gland**. Probe it and note the extent of the gland. On the right side of the head is a straight groove which extends to a

depression just behind the base of the anterior tentacle. This depression is the **common genital pore**, the animal being hermaphroditic. The **anus** is a small opening just beneath the respiratory pore at the end of a deep groove. It is not easily observed from the outside.

Note the asymmetry of the animal. Its spiral twist has been the cause of the loss of the primitive bilateral symmetry of the visceral mass and shell. They are not borne squarely above the foot, but obliquely and to the left. The respiratory pore (that is, the opening of the mantle cavity) and the anus have not a median posterior position, as must have been the case in the primitive ancestor of the animal, but have suffered displacement to the right side. Other instances of asymmetry will be noticed as the dissection proceeds.

Exercise 1. Draw a side view of the animal seen from the right side as it appears when it is moving and when the head and foot are out of the shell, and label the parts above mentioned.

Exercise 2. Draw a similar sketch of a front view of the animal.

Remove the dead animal from its shell in the following way: place it for five minutes in strong alcohol, or for half a minute in very hot (not boiling) water, in order to loosen the shell; then twist it out of the shell; this must be done very gently, or the animal will be torn.

Exercise 3. Draw the shell showing its opening on the right.

Break off a portion of the edge of the shell and examine the broken edge with the aid of a hand lens. Note the three layers which compose the shell: the inner **pearly layer**, which has been secreted by the entire surface of the mantle; the thick **middle layer** and the thin **outer layer**, or **periostracum**, which have been secreted by the collar. The periostracum is a horny, uncalcified layer, which is usually more or less worn off.

The Internal Organs. Take the snail, deprived of its shell, in the hand, and remembering that the outer side of each whorl of the spiral is on the left side of the animal and that the inner side of the whorl is on the right, observe the extent of the mantle

cavity. Put the blowpipe through the respiratory pore and blow into the mantle cavity. It will be seen to extend from the collar to the posterior side of the first whorl. Examine the mantle wall with a hand lens and against the light. The network of blood vessels which constitutes the **lung** will be seen. On the hinder border of the mantle cavity note the **kidney**, an elongated, light-colored, triangular organ; just in front of it and beneath it — that is, between it and the mantle cavity — is the **heart** within the **pericardium**; note the two chambers of the heart, the dorsal **auricle** and the more ventrally placed and larger **ventricle**. Back of the kidney is the dark-colored **liver**, which, with the **intestine** and the light-colored **reproductive tract**, occupies the remainder of the coils of the spiral. Note the **rectum**, a broad tube on the inner (right) border of the mantle cavity going to the **anus**. Cut a small hole in it, and through this pass a probe to the anus.

The Mantle Cavity. Lay this open in the following way: with fine scissors cut through the collar at the respiratory pore; then make an incision in the mantle wall from this opening, following the collar round the outer side of the whorl to the heart; continue the incision across the artery leading out of the heart, and through the delicate membrane between the liver and the kidney to the rectum, at the inner border of the whorl. The mantle can now be laid back and its cavity with the organs exposed. The broad rectum will be seen running along the entire inner border of the mantle cavity. Now make an additional incision from the respiratory pore along the inner (lower) border of the rectum as far as the kidney. Lay back the mantle and pin it down as flat as possible under water. Identify the heart within the pericardium, the kidney, and the rectum.

The Respiratory and Circulatory Systems. Observe the **lung** (the network of blood vessels in the inner surface of the mantle) and the large **pulmonary vein**, which runs along the kidney to the heart. Slit open the pericardium. The two chambers of the heart will be more distinctly seen, the thin-walled **auricle** into which the vein runs and the larger **ventricle**. Back of the latter the **aorta** passes into the viscera; its cut end will be seen.

The process of respiration and circulation is the following:

the air is drawn into the mantle cavity through the respiratory pore; this is accomplished by the alternate enlarging and contracting of the cavity by means of the muscular body wall which constitutes its floor. Notice the longitudinal and the transverse muscles in this floor. The blood circulating in the lung is oxygenated and passes into the heart through the pulmonary vein as arterial blood. It is forced by the heart through the aorta, and thence through arteries to all parts of the body, whence it returns through blood lacunæ to the lung.

The Excretory System. The large **kidney** has already been seen. It is a sac the glandular projections of the walls of which almost fill its lumen. As is the case with pelecypods, the kidney communicates with the pericardial space through a fine canal and also with the mantle cavity by means of a **ureter**. The pericardial canal is opposite the ventricle and cannot be seen easily. The ureter may be easily traced. It is a wide canal which leaves the kidney at its forward end near the place where the pulmonary vein approaches the kidney; it first runs along the inner side of the kidney to its hinder end; here it doubles on itself and passes forward to the inner edge of the mantle, where it runs beside the rectum to a point near the respiratory pore and opens into the mantle cavity.

It will be noticed that the heart and the kidneys are both asymmetrical organs. The heart has but one auricle; it will be remembered that in the pelecypod the auricles are paired organs; one of the pair must thus be wanting in the snail. There is also only one kidney and one ureter, instead of a pair of each, as in the pelecypod. It is the left member of the pair in each case which is wanting.

Exercise 4. Draw a view of the inner surface of the mantle on a scale of 3, showing the organs mentioned above; label all.

The Digestive System. Pass a bristle through the anus into the rectum in order to mark it. With two strong pins firmly fasten the extreme forward end of the animal's foot and also its hinder end to the wax of the dissecting pan. With sharp, fine scissors cut through the floor of the mantle cavity and the collar in the median

line; carry the incision forward in the median line along the head between the base of the tentacles to the mouth. Care should be taken in making this incision not to cut the organs beneath. Spread the flaps as widely as possible to the right and left and pin them down, thus exposing the organs in the forward part of the body.

The white organs on the right side of the body belong to the reproductive system. The large, dark organ in the center, or on the animal's left, is the **stomach**. Find the slender, curved **œsophagus**, which leads forward from it to the dorsal side of the large, muscular **pharynx**. The œsophagus is encircled by the white nerve collar, the dorsal portion of which is the brain. If, however, the animal died in a retracted condition, the pharynx may have slipped back through the nerve collar, which would then encircle the forward end of that organ. Note the two white, leaflike **salivary glands** which lie close against the wall of the stomach, and trace their **ducts** forward to the pharynx. Lying above and across the œsophagus is the white, cylindrical penis, which will be seen to extend from the genital pore at the right of the mouth and to bend sharply on itself. The bend of the penis is connected by a long retractor muscle to the dorsal body wall. Find it; cut it and pin the penis on the animal's right. Note the broad, glistening retractor muscle connecting the pharynx with the ventral, posterior body wall. Notice its shape; with strong forceps pull it loose from the pharynx and entirely remove it. Beneath it, note the still larger retractor muscle running from the forward end of the head back to the same locality. What is the function of these different retractors? The dark-colored sheaths and the retractor muscles of the tentacles will also be seen; trace these muscles to their origin. Find the nerve which passes from the brain into each tentacle.

Separating the delicate filaments connecting the stomach with the surrounding organs, and pushing it and the œsophagus to the animal's left, find the large nervous mass which forms the ventral portion of the nerve collar, and the nerves radiating from it. It is an agglomeration of ganglia, being made up principally of the **pedal** and the **visceral ganglia**. Press the reproductive organs to the animal's right and pin them down. The **receptaculum**

seminis, a small, spherical body the size of a small shot, at the end of a long tube, will be found in a bend of the intestine, from which it must be separated.

We turn now to the other end of the **intestine**. Trace the **rectum** from the **anus** to the point where it is surrounded by the **liver** and carefully dissect away the integument which covers the inner surface of the whorl. The light-colored **hermaphroditic gland** will be exposed. Then remove the delicate integument which covers the outer surface of the whorl, and the dark-brown **liver** will be exposed. Press the liver away from the intestine and completely free it, being careful not to break either liver or intestine. Great care should also be taken not to injure the hermaphroditic gland, which is the yellowish mass on the inner side of the last whorl, or the **hermaphroditic duct** leading away from it. Note that the liver is composed of two masses, the smaller of which is of spiral form and occupies the apex of the shell; the larger is subdivided into three lobes. Note also the two main **bile ducts** which join the liver with the intestine. The **visceral artery** will be seen lying upon the liver, sending branches off on both sides, and must not be confused with the bile ducts, which it resembles in appearance. It carries blood from the aorta to the top of the spiral, supplying all the organs of the visceral mass. At the point where the bile ducts communicate with the intestine, that organ makes a sharp turn.

Spread out the digestive tract to the animal's left and pin it down, without removing or breaking the hermaphroditic gland or duct. The stomach will be seen to extend nearly to the liver. Next comes the intestine, which soon makes the sharp turn above mentioned, receives the bile ducts, and passes into the rectum at the right side of the mantle cavity.

Exercise 5. Draw an outline of the alimentary tract from the mouth to the anus on a scale of 2 and label all its parts.

Study the structure of the pharynx. Pass a probe into the mouth and notice the extent of the pharyngeal cavity. Notice the transverse, horny **jaw** in the roof of the mouth. With a sharp knife split the dorsal pharyngeal wall, taking care not to injure

the nerve collar or reproductive organs. Notice that the connection of the œsophagus and the salivary ducts with the pharynx is near the dorsal wall of the latter organ. Observe the thick, muscular **tongue**, the organ by means of which the animal grinds its food. Its surface is covered with a ribbon set with small teeth, called the **radula**. This can be easily pulled off with the forceps. Mount it on a slide in water or glycerine and study its surface under a high power of the microscope.

Exercise 6. Make a drawing of several of the teeth.

The Reproductive System. The snail is hermaphroditic, but is not self-fertilizing. The **hermaphroditic gland**, which at different times produces both spermatozoa and ova, is situated on the inner side of the smaller lobe of the liver. The **hermaphroditic duct** is a delicate, white, convoluted tube, which goes from the hermaphroditic gland to the **albuminous gland**, a large, white body lying near the liver. From this organ the **oviduct** and **vas deferens** pass forward to the genital opening near the mouth. These canals are side by side and connected with each other for the first part of their course, but may be distinguished by the character of their walls, the oviduct having folded, glandular walls, whereas the vas deferens is a narrow tube with thin walls. It is through the latter canal that spermatozoa pass out from the hermaphroditic duct; the ova pass out through the oviduct, the glandular walls of which, together with the albuminous gland, secrete the albumen which surrounds them when they are extruded. Near their forward end these two canals separate. The oviduct loses its glandular walls, becomes cylindrical in shape, and expands to form the **vagina**. This is a thick-walled vessel with which are connected the following accessory genital organs: the **receptaculum seminis**, a small, spherical organ, already mentioned, lying in the bend of the intestine and joined with the vagina by means of a long tube which lies along the oviduct; the **mucous glands**, two bunches of tubular glands; and the **dart sac**, a thick-walled sac which contains a **calcareous spicule**. Identify these organs.

The **vas deferens**, after separating from the oviduct, passes under the retractor muscles of the tentacle to the distal end of

the **penis**. This organ has already been noted; it is tubular in shape and lies in a bent position across the œsophagus. A retractor muscle inserted at the bend connects it with the dorsal body wall. At the point where the vas deferens meets it observe the **flagellum**, a long, tubular sac into which spermatozoa pass from the vas deferens and where they are massed together to form **spermatophores**. Both penis and vagina communicate, side by side, with the **genital cloaca**, which opens to the exterior through the common genital pore.

When two animals pair each receives a spermatophore from the other. This passes into the receptaculum seminis, which is thus filled with the spermatozoa of the other animal, and these finally fertilize the eggs as they pass into the vagina from the oviduct.

Exercise 7. Make a semidiagrammatic drawing of the reproductive organs on a scale of 2.

Split the dart sac and take out the dart; mount it on a slide in water or in glycerine and examine it under a compound microscope.

Exercise 8. Draw the dart.

The Nervous System. Sever the œsophagus and remove the reproductive and digestive systems, leaving the pharynx in the body and taking care not to injure any of the nerves. The principal ganglia are contained in the **nerve collar**. The two **supraœsophageal ganglia**, which constitute the brain, will be seen joined by a broad **transverse commissure**. From their anterior surface nerves run to the tentacles, and from their inner surface a pair of nerves run to the posterior end of the pharynx, where they meet a pair of small **pharyngeal ganglia**. The **supraœsophageal ganglia** are connected by broad connectives with the **subœsophageal ganglia**. Remove the pharynx from the body. By slightly scraping the subœsophageal ganglia with a small scalpel, it will be seen to consist of two principal ganglionic masses. The forward mass is a pair of ganglia, the **pedal ganglia**; the hinder mass consists of the large **visceral ganglia**, at the side of which is

the pair of small **pleural ganglia**. Observe the nerves radiating from the subœsophageal ganglia, and determine as far as possible to what organs they go.

Exercise 9. Make a semidiagrammatic drawing of the nervous system.

Organs of Special Sense. The **eyes** of the snail at the end of the posterior tentacles have already been noted. They are easily seen in a large animal which has its tentacles extended. The snail is also provided with a pair of **auditory organs**. They consist of two small sacs embedded in the pedal ganglia. In order to see them cut off the subœsophageal ganglion, mount it in glycerine, and examine it under a compound microscope. The auditory nerves are very delicate and come from the supraœsophageal ganglia.

CLASS: *Cephalopoda*

A SQUID (*LOLIGO PEALI*)

The squid is a very common marine animal. It is gregarious in its habits and swims about in large schools in search of its food, which consists of crustaceans, small fishes, etc. When alarmed by the presence of its natural enemies, which are many kinds of fishes, it clouds and darkens the water by ejecting into it an ink-like fluid. The fresh animals are studied with greater profit than those which have been preserved in alcohol, as this changes the nature and appearance of many of the organs. The best preservative is formalin.

External Anatomy. Observe the cylindrical, bilaterally symmetrical body; at one end is a pair of broad **fins**, and at the other the movable **head** bearing ten **arms**, two of which are much longer than the others. The **mouth** is at the base of and surrounded by the arms, and the brown, horny **beak** may usually be seen protruding partly from it. The large **eyes** are on the sides of the head at the base of the arms. Each is covered by a cornea, which is pierced by a small hole between the eye and the base of the arms, so that sea water is admitted freely into the space between the cornea and the pupil, and may take the place of the aqueous humor of the vertebrate eye. A transverse fold on the side of the head between the eye and the body is the **olfactory organ**. Observe the pigment spots, or **chromatophores**, which are distributed over the body; they are constantly changing in shape and size during life, causing corresponding changes in the color and appearance of the animal.

The head and neck project from the large **mantle cavity**, into which they can be partially withdrawn by means of powerful retractor muscles, in very much the same way that a snail's head and foot can be withdrawn into its shell. The **siphon**, or **funnel**, a large, funnel-shaped organ at the base of the head, also projects from it and can be similarly withdrawn. Gently probe the mantle cavity and determine its extent. The **mantle** constitutes the outer surface of the body. It will be seen to be a cylindrical

structure with thick, muscular walls within which lie all the viscera of the animal; its free edge is called the **collar**, as in the snail. It is also necessary to observe that the mantle is not a paired organ, as it is in the clam, but an unpaired one, as in the snail. The squid has no foot, as has the clam or the snail, but morphological equivalents of the foot are present in the arms and the siphon.

Since in all mollusks the foot or its equivalent occupies a ventral position, and the visceral mass a dorsal position, the arms of the squid, together with the head, must be on its ventral side, and the opposite end with the broad fins must be dorsal; the animal is thus enormously extended dorsoventrally. It will be readily seen also that the mantle falls as a cylindrical fold from the dorsal end about the entire body, exactly as it does in the case of the snail. In fact, if the coils of the snail's visceral mass could be straightened out, the mantle would fall as a cylindrical fold from its dorsal end and terminate in the collar below, in the same way as in the squid. The morphologically posterior side of the animal is that on which the siphon is situated; the anterior side is the opposite one. In common parlance, however, the head end of the squid is called the forward end, and the fin-bearing end, the hinder. The side bearing the fins is likewise called the upper side or back, and the opposite side, on which is the siphon, the under or lower side. These terms, although incorrect in a strictly morphological sense, are much more convenient for general use and will be employed hereafter in these directions.

The mantle of the squid does not secrete an external shell, as does that of the snail and the clam; in a long pocket on the upper side, however, is an elongate, horny structure, called the **pen**, which is secreted by the mantle and is the equivalent of the shell of other mollusks.

Make a short, shallow incision in the upper surface of the mantle, beginning with the collar. Turn the flaps aside and note the brown, horny **pen** lying beneath. Do not remove it at present, as the dissection of the parts beneath might be disturbed by its removal.

Exercise 1. Make a drawing of the underside of the animal.

Note that the arms may be divided into a right and a left group, each containing five arms. Observe a single arm; how many rows of suckers has it? Observe the structure of a sucker. Note the difference between the two long arms and the others in the place of origin and the arrangement of the suckers.

The Mantle Cavity. Open the mantle cavity by a longitudinal incision through the thick mantle wall of the under side of the body to one side of the median line, running from the collar to the apex of the animal, taking care not to injure the delicate organs within. Notice, in the first place, that the collar is not attached to the head at any point of its circumference; and also that on the inner surface of the mantle, on the upper side of the body in the median line and also on each lateral surface, there is an elongate, cartilaginous structure which fits into a corresponding cartilage on the body — an arrangement which enables the collar to be applied very closely to the head.

Place the animal in water with the head away from you and pin down the flaps of the mantle. Observe the soft **visceral mass** within it, and notice that it is fused with the mantle only in the median line of the back; also that the pen, which is embedded in the mantle, protects the viscera on that side. Observe the **siphon** and probe it. It will be seen to be a funnel-shaped tube communicating between the mantle cavity and the outside. Slit it open and observe the flaplike **valve** at the forward end. Notice the **lateral pockets** on each side of the siphon which open toward the mantle cavity and occupy the space between the siphon and the median line of the back. They are separated from the siphon by the lateral, cartilaginous rods above mentioned. It will be seen that while water can easily pass into the mantle cavity from the outside all around the neck, a contraction of the muscular wall of the mantle would force the water out through the siphon only, as that which is forced into the lateral pockets would at once swell them out and close the spaces at the sides of the siphon. It is, in fact, by thus shooting the water in the mantle cavity forcibly through the siphon that the animal swims.

Note the two large **retractor muscles** of the siphon and beneath them the two larger **retractor muscles** of the head.

Observe again the **visceral mass**; it is covered by a thin, transparent membrane, the **body wall**, the extreme thinness of which is correlated with the thickness of the mantle which covers it. If the animal is a female that fact may be known by the presence of two very large, transversely striated bodies, called the **nidamental glands**, which lie near the center of the body, and are a part of the reproductive system. Carefully remove these in order to expose the organs beneath. If the animal is a male (and the student should obtain a male if possible) it can be recognized by the absence of nidamental glands and also by the presence of the **testis**, a large, white, tubular organ which lies near the median line toward the hinder end of the animal. In the female the **ovary**, which occupies a similar position, is often very full of the granular ova.

Notice in the mantle cavity the pair of plumose **gills** to the right and the left of the visceral mass, each attached to the inner surface of the mantle by a **mesentery**. Between the retractor muscles of the siphon and extending from the base of the gills forward to the siphon is the **rectum**, which terminates in the **anus**, with its two projecting **valves**. Find the valves. Beneath the rectum is the **ink bag**, and both are attached to the organs beneath them by a **mesentery**. The ink bag communicates with the rectum by means of a duct which joins it near the anus; this duct may be found by slitting the rectum for a short distance back of the anus, when the small opening may be made to appear by squeezing the ink bag and forcing the ink into the rectum. The ink, together with the fecal matter from the intestine and other waste products, is voided into the sea water through the siphon; its function is to cloud the water and thus hide the animal from its enemies. In the male animal notice the long, tubular **penis** to the right of the rectum (the animal's left); if the animal is a female, the thick-walled **oviduct** will be seen in a corresponding position.

At the base of each gill note a round, disk-like body; this is a **branchial heart**, from which blood is sent into the gills; near each branchial heart toward the median line and running forward alongside the rectum is an elongate, transparent structure, the **kidney**. The position of the kidneys may be determined by the

two conspicuous white veins — the **precaval veins** — which pass through them longitudinally from one end to the other. These veins are wide, spongy-walled structures which run to the branchial hearts and will be seen toward the median line from those organs. Just beneath the base of the two kidneys and between the branchial hearts is the **median**, or **systemic**, **heart**, into which blood pours from the gills. Note a median artery, the **posterior aorta**, which leads back from the systemic heart; it branches into three large **mantle arteries**, two of which pass to the right and left, respectively, and enter the mantle at the side, while the other passes into the mantle in the median line; it is through these arteries that the mantle is supplied with blood.

On each side between the base of the gill and the rectum and extending parallel with the latter organ, notice again the delicate **kidney**; each of the pair of kidneys extends backward to a point a short distance back of the branchial heart, and forward to a point back of the base of the ink bag, where it communicates with the mantle cavity through a small opening. Find the two openings by lifting up the body wall with forceps and blowing on it with a blowpipe, when they will appear.

Running back from the branchial heart on each side is a wide vessel, the **postcaval vein**; the forward end of this vein has thick, spongy walls like those of the precavals and is easily seen; the greater part of it, however, has extremely thin walls and can be seen with difficulty. Near the base of each gill note also a vessel which runs forward and laterally into the mantle; this is the **mantle vein**. Just back of this vein is a muscle which connects the gill with the mantle; it is the **branchial retractor muscle.**

Note the two large **stellate ganglia** in the forward part of the inner surface of the mantle, and the radiating nerves which each ganglion sends into the mantle.

In the hinder portion of the visceral mass in the male animal observe on the animal's left (the observer's right), just behind the branchial heart, a coiled tube, the **vas deferens**, and in the female the thick-walled **oviduct**. Extending farther back and near the median line is the large, white **testis** in the male and the large **ovary** in the female.

Exercise 2. Make a large sketch of the mantle cavity of the animal showing these organs, and label all.

With fine scissors and forceps carefully dissect away the delicate transparent body wall and expose the organs beneath, taking care not to injure them.

The Excretory System. The **kidneys** and their external openings have already been observed. As in other mollusks, the kidneys also communicate with the pericardial space.

The Circulatory and Respiratory Systems. Pushing aside the organs which partly conceal it, observe again the **systemic heart**; note its shape and slightly asymmetrical position. Extending from its forward end is the **anterior aorta**, which takes blood to the forward part of the body; its course cannot be followed at present. The hinder part of the body is supplied with blood by the **posterior aorta**. This vessel, as we have already seen, leaves the hinder end of the systemic heart; it sends off two pairs of small **arteries** to the stomach and to other viscera, and then branches into the three **mantle arteries** already mentioned. Find them all and trace them as far as possible. Observe again the two **branchial hearts**. Note the **branchial artery**, by which blood passes from the branchial heart to the gill; also the **branchial vein**, through which it passes from the gill to the systemic heart.

Observe again the veins which bring the blood to the branchial hearts. The **precavals** bring blood from the forward part of the body. Trace them forward. They enter the kidneys near the forward end of those organs and traverse their glandular walls back to the branchial heart. Press aside the rectum and the forward end of the kidneys and observe where the two **precavals** come from beneath and enter the kidneys. With fine scissors cut the connective tissue which binds the veins, and also the mesentery which holds down the rectum and the ink bag, and turn these organs back. Trace the two **precavals** forward; they will be seen to come from a delicate **median vein** which may be followed into the head. Observe again the **postcaval veins**, which bring blood from the hinder part of the body and join the branchial hearts near the same place as the precavals. Their forward ends also traverse the glandular walls of the kidneys and are here conspicuous; back of

these they are much wider, but are very thin-walled and not easily seen. Trace them as far as possible. Observe again the **mantle veins**, which bring blood from the mantle to the branchial hearts.

The course of the blood is the following: it enters the branchial hearts through the postcaval, precaval, and mantle veins; the contraction of these hearts sends it into the branchial arteries which pass along the upper side of the gills; it then traverses the delicate, transverse filaments of the gills and becomes oxygenated, when it collects again in the branchial veins on the opposite side of the gills; through these it passes to the systemic heart, whence it is sent through the anterior and posterior aortas to the different parts of the body.

Exercise 3. Make a diagrammatic drawing of the circulatory and the respiratory systems.

The Digestive System. Remove the kidneys and precaval veins. Beneath them will be seen a large, glandular, bilobed organ of somewhat doubtful function, called the **pancreas**. At its forward end a pair of cylindrical organs, the **liver ducts**, will be seen entering it from the **liver**. The pancreas is made up of anastomosing, glandular projections of the walls of these ducts. Remove the gills, branchial hearts, systemic heart, and hinder arteries. The delicate body wall should be completely removed from the entire visceral mass, and great care be taken not to injure the **stomach pouch** beneath. This latter organ is a large bag with thin, transparent walls which extends to the extreme hinder end of the body; beneath it will be seen the large **testis** or **ovary**, according to the sex of the animal. This pouch is not really a part of the stomach, notwithstanding its name, but is a reservoir for the secretions of the liver, which communicates with it through the liver ducts. Carefully loosen the stomach pouch without separating it from the body and let it float in the water of the dissecting pan. It communicates with the thick-walled **stomach**, which lies just in front of it, but food substances are prevented from passing into it from the stomach by valves. Loosen the stomach, noticing that it is bound to the ovary or testis by an artery, the **genital artery**. At the forward end of the stomach are the **intestine** and the œsoph-

agus, side by side; the former passes between the two halves of the pancreas and ends with the **rectum**; the œsophagus goes forward side by side with the anterior aorta to the middle of the large liver and passes through it in company with the aorta. The œsophagus is easily found by turning the stomach over. A small **ganglion** with radiating nerves will be seen by the side of the œsophagus near its junction with the stomach.

The **liver** is an elongated body lying between the retractor muscles of the head and of the siphon; two ducts emerge from it and pass through the pancreas to the stomach pouch. Loosen and remove the connective tissue around the liver and raise it up; the œsophagus and the aorta will be seen to pass through it toward the back of the animal and then forward to the head.

Remove the siphon and split the wall of the head; trace the **œsophagus** to its forward end. It will be seen to pass through the ganglionic mass which constitutes the central nervous system, and which is surrounded by a hard, cartilaginous capsule. In front of this it meets and ends in the bulbous **pharynx**. Near the forward end of the liver, and resting upon the œsophagus, will be seen the **median salivary gland**, the duct of which may be traced to the pharynx; near the hinder end of the pharynx is a pair of smaller **salivary glands**, which also communicate with it. Trace their ducts to the end. The alimentary canal will thus be seen to consist of the following organs: the muscular **pharynx**, with which a pair of small **salivary glands** and a single, large **salivary gland** communicate; the narrow **œsophagus**; the thick-walled **stomach**; the **stomach pouch**, which communicates with the stomach by a valved opening; the elongated **liver**, which communicates with the **stomach pouch** by two long **ducts**; the bilobed **pancreas**; the **intestine**, which leaves the stomach near the point where the œsophagus enters it; the **rectum**, which is joined by the **ink bag** and passes to the **anus**.

Exercise 4. Take the alimentary tract out of the body, pin it down, and make a drawing of it; label all its divisions.

Slit open the stomach and examine its ridges. Slit open the pharynx on the upper side; note the large, chitinous **jaws** and the

radula. The latter organ, like the radula of snails, is used in chewing the food; examine its surface under a microscope and note the calcareous **teeth**.

Exercise 5. Make a drawing of the jaws.

Exercise 6. Make a drawing of several of the teeth of the radula.

The Reproductive System: the Male. The principal genital organs have already been observed. The single, median **testis** is a large, flat organ, dorsal to the stomach pouch, in the hinder portion of the visceral mass; the genital artery joins it with the surface of the stomach. The testis has no direct connection with the **vas deferens**, but is surrounded by a thin, transparent membrane within which it lies as in a capsule, and into which the spermatozoa escape. The **vas deferens**, which is also unpaired, communicates with this capsule. It is a long and much-twisted tube with several wide, glandular regions, and lies, bound by connective tissue into a compact mass, on the left side of the viscera. Take the entire system out of the body, put it into water, loosen and straighten out, as far as possible, the convolutions of the vas deferens. Beginning with its hinder end we find first a narrow, convoluted tube, and then follows a thicker, tubular portion, the **vesicula seminalis**; near the forward end of this portion is a glandular body, the **prostate gland**, and a **membranous sac**; a long, straight, narrow portion comes next, which widens to form the **spermatophoric sac**, within which the spermatophores are formed; then follows the tubular **penis**, which forms the forward end of the tract and has already been observed lying in the mantle cavity to the left of the rectum.

Exercise 7, a. Make a drawing of the male genital tract.

Exercise 7, b. Open the spermatophoric sac and look for spermatophores; they are slender, white objects about half an inch long. Mount several on a slide and make a drawing of one.

The Female. The single **ovary**, like the testis, is a very large, elongated gland occupying the hinder end of the visceral mass and surrounded by a **capsule**. The **oviduct** communicates with this capsule; it passes forward along the left side of the visceral mass, its walls becoming thickened in its course to form the **oviducal**

gland, and opens into the mantle cavity by means of a large, thick-lipped aperture to the left of the rectum.

Two pairs of prominent accessory glands are present in the female, the large, white, finely striated **nidamental glands**, which cover up most of the other organs of the visceral mass, and beneath them the much smaller **accessory nidamental glands**, which are pink-colored in life and lie to the right and left of the rectum; both pairs of glands open at their forward ends into the mantle cavity. These glands secrete the egg capsules, which protect the eggs after they are laid and while development is going on within them.

Exercise 7, c. Make a drawing of the female organs.

The Nervous System. In the position of the principal ganglia the squid resembles the snail, but these ganglia are difficult to observe in a dissection because they are compactly massed together and are protected by a cartilaginous capsule, which forms a sort of skull. The cerebral or **supraœsophageal ganglia** form a large mass above the œsophagus; broad commissures join it with the subœsophageal mass, which is composed of the **visceral, pedal**, and, in front of the latter, the **brachial ganglia**. Connected with the sides of the cerebral mass are the two **optic nerves**, which widen out to form the large **optic ganglia**, and running forward from it are two small nerves which connect it with the **suprapharyngeal ganglia**, a small mass above the hinder end of the pharynx. From these ganglia small nerves pass around the œsophagus to the pair of **subpharyngeal** ganglia. From the forward surface of the subœsophageal mass, that is, from the brachial ganglia, ten nerves pass off to the arms. These may be seen on the inner surface of the head after the removal of the pharynx. From the hinder surface of the visceral ganglia **pleural nerves** run to the **stellate ganglia** in the mantle. Trace these nerves from the stellate ganglia to their source.

The Pen. Make a longitudinal slit in the mantle on the back of the animal and remove the pen; it will be seen to lie quite loosely in its sac.

Exercise 8. Draw the pen.

PHYLUM ECHINODERMATA

Class: *Asteroidea*

A STARFISH

Several species of starfishes are common along our coasts, the most familiar being *Asterias vulgaris*, the common New England form, which is found along the entire Atlantic coast, and *Asterias forbsii*, which is common south of Cape Cod. They are remarkably sluggish creatures which live on the sea bottom, moving slowly, often in large numbers, from place to place and feeding on the various mollusks which come in their way.

Two specimens will be needed for this dissection, a dried one for the study of the hard parts, and one that is fresh or has been preserved in formalin or alcohol for the study of the internal and other soft parts. To prepare a dried starfish the live animal should be placed in fresh water for half an hour. It should then be placed in alcohol for an hour, and then dried thoroughly. If only preserved material is at hand, the animals may be simply dried. The fresh water and alcohol expand the body wall of the animals and prevent it from collapsing after death.

Study the external characters of a fresh or a preserved specimen. Observe the color and the flattened, radiate body form. The body is composed of a **central disk** from which radiate five **arms**, or **rays**. All these rays are normally of equal length. Specimens are often found, however, in which the length of the rays is unequal. This is due to the fact that starfishes often lose one or more of their rays by accident; the missing member is soon replaced by a new ray, but while it is growing out it will be shorter than the others. The spaces between the rays are called **interrays**. In the center of the under surface of the disk is the **mouth**; hence this surface of the animal is called the **oral surface**. Its upper surface is called the **aboral surface**.

In the aboral surface of the disk notice the red **madreporite** (in preserved specimens it may have lost its color and be white). Examine it on the dried specimen with the aid of a hand lens or the low power of a compound microscope and notice its porous structure. In the aboral surface is also the **anus**; it is a very small opening and will be difficult or impossible to see in the specimens at hand. Note the short fixed **spines** covering the entire aboral surface. Each one is a part of small **calcareous plate** buried beneath the integument. The entire body wall of the animal is made up largely of these plates, which give it its stiffness. The plates are not, however, connected with one another except by muscles and connective tissue, and the animal's arms are flexible and freely movable. Demonstrate this fact with your specimen. In the dried animal this flexibility no longer appears, as the entire body wall has been rendered rigid by the drying. In the soft places between the plates note the delicate, tubular projections of the integument; they are the contractile **papulæ**, and are organs of respiration and excretion and possibly also of sensation. With the aid of a hand lens find, around the base of each spine, the **pedicellariæ**; these are minute, pincer-like organs of somewhat uncertain function, but they probably aid in keeping the surface of the animal free from particles of dirt and from minute organisms which might be harmful.

The two arms which inclose the madreporite between their bases are called the **bivium**; the remaining three, the **trivium.** How can a plane be passed through the body so as to divide it into two symmetrical halves?

Exercise 1. Make a life-size drawing of the aboral aspect of the animal and label all the features observed.

On the oral surface observe the deep groove which extends from the mouth along each arm to its tip. This is the **ambulacral groove.** Observe the two rows of movable spines which fringe each side of the groove; note also the five pairs of movable spines which surround the mouth. Separate these spines and observe the mouth surrounded by a circular membrane, the **peristome.**

From the sides of each ambulacral groove two zigzag rows of soft tentacles project. These are the **ambulacral feet**; they are muscular tubes with sucker disks at their ends and are the organs of locomotion. Scrape the feet from a portion of the groove and examine its sides; note the slender, transverse **calcareous plates** which form it, and the round openings between them, called the **ambulacral pores,** through which branches from the feet project into the body cavity. Note the zigzag nature of each of the two rows of these pores. Notice also the delicate cord which extends along the median line of the groove; it is the main **nerve** of the arm; it proceeds from a **nerve ring** in the central disk to the tip of the arm. Follow it to the tip and note the red pigment spot with which it ends. This is the **eye.** In preserved specimens the pigment may have lost its color.

Exercise 2. Make a life-size drawing of the oral aspect of the animal and label all these features.

Scrape off several pedicellariæ, mount them on a slide, and examine them under a compound microscope. By pressing on the cover glass with a needle, the jaws can be made to open and shut; try it.

Exercise 3. Draw a pedicellaria on a large scale.

Cut off the aboral wall of the severed arm of the dried specimen and scrape away the remains of the internal organs and the ambulacral feet. Study the inner surface of the ambulacral groove. Note the two rows of slender **transverse plates** which form the sides of the groove, and on each side between every two plates, the minute **ambulacral pore.**

Exercise 4. Make a drawing on a scale of 3 of the inner surface of the ambulacral groove, showing the plates and the pores.

Cut off the aboral wall of the central disk of the dried specimen, scrape away the remains of the internal organs, and study the arrangement of the plates in the inner surface of the oral body wall. Note the circular **mouth** protected by converging spines, and also the membranous **peristome.** Observe the convergence of the five

arms about the peristome; note also the **interradial partitions** which separate the base of the arms.

Exercise 5. Make a life-size drawing showing these features.

Internal Anatomy. Remove the entire aboral body wall from the trivium and the central disk of the fresh or preserved specimen, with the exception of the madreporite which must not be removed, being very careful not to injure the organs beneath. Study the internal organs and observe the following systems:

The Digestive System. Observe the large saclike **stomach**, which almost fills the central disk. Its walls are much folded, and five short, baglike pouches extend from it into the five arms. When the animal feeds the stomach is everted and thrust out through the mouth and about its prey. It is drawn in again by means of five pairs of **retractor muscles**, which connect the stomach pouches with the inner surface of the ambulacral grooves. Find the pair of retractors belonging to each stomach pouch. Communicating with the aboral portion of the stomach are five large, radial digestive glands, which are usually called **livers**. Each gland almost fills an arm; it is made up of two main trunks, from which project numerous side branches; the two ducts leading from the two trunks in each arm unite to form a single duct which passes to the stomach. Each trunk is suspended from the aboral wall of the arm by two **mesenteries**. Find the mesenteries in one of the bivial arms. Study the structure of the livers. The stomach is connected with the mouth by a short **œsophagus**, and from its upper surface a short, slender **intestine** passes to the anus. Connected with the intestine is a small branched diverticulum, the **intestinal cæcum**. The intestine, together with its cæcum, may have been removed when the aboral body wall was taken off. If this is the case look for them on the portion of the aboral wall which was taken off and notice also the position of the anus.

The Reproductive System. The sexes of the starfishes are separate. The sexual organs are branched **glandular organs**, ten in number, which lie in the proximal portion of the rays and open to the outside through minute pores in the aboral walls of the interrays. Two glands will be found in each ray extending from

the base of the ray toward its tip. The actual size of these organs depends entirely upon the sexual condition of the animal. In young or immature animals they may be no more than half an inch long or less, while in reproducing animals they may extend almost to the tip of the ray. The **testis** of the male and the **ovary** of the female animal do not differ from each other in general appearance. In the mature female, however, the ovaries have a light-yellow color, and in the mature male the testes are white and are less voluminous than the ovaries.

Exercise 6. Make a semidiagrammatic drawing of the animal showing the details of the digestive and reproductive systems; label all.

Remove the stomach and the reproductive organs from the body, taking care not to injure the sinuous stone canal which is at one side of the former.

The Ambulacral System. This is the most characteristic system of organs in the Echinodermata. In the starfish it consists of the following organs: a circular canal, called the **ring canal**, surrounding the mouth; connected with this canal are nine minute, lobated sacs called the **racemose** or **Tiedemann's vesicles**, two being located in each interray except the one in which is the stone canal, where but one is present; five **radial canals**, which pass from the ring canal along the median line of the ambulacral grooves to the tips of the arms; the **ambulacral feet**, which are connected with the radial canals by short **branch canals**, and also project through the ambulacral pores into the body cavity, where they expand to form small sacs called **ampullæ**; a sinuous canal, called the **stone canal**, which connects the ring canal with the madreporite; the **madreporite**, a porous plate by means of which the entire system is placed in communication with the outside sea water.

In studying this system find first the madreporite and the stone canal, and trace the latter from the madreporite to the ring canal. Remove the spines which project over the peristome and find the ring canal. It is a delicate tube, of about the diameter of a needle, which surrounds the mouth, running around the base of the arms at the point where the peristome joins them; it is thus, like the radial canals, outside the body cavity. Remove some of the am-

bulacral feet from a ray and find again the delicate radial canal which lies along the middle of the ambulacral groove. Trace it to the ring canal. Cut the aboral body wall from one of the bivial rays, remove the liver, and observe the ampullæ. Press them and notice that the feet are thereby extended.

The ambulacral system will be seen to be a system of tubes extending throughout the body and in communication with the sea water. They are filled with a fluid which is not pure sea water, but is rather a watery serum in which float amœboid cells. This fluid is driven into the tubelike ambulacral feet, which thereby acquire rigidity and are extended. The system is the locomotory system of the animal. It moves by extending the feet, attaching the sucker disks at their ends to some stationary object, and then drawing them in. The animal is thus able to pull itself slowly along. The ambulacral system possibly also exercises excretory and respiratory functions.

Exercise 7. Draw a diagram of the ambulacral system.

There are no special respiratory and excretory organs. These functions are exercised by the papulæ and possibly the ambulacral feet.

The **nervous system** consists of a circumoral **nerve ring**, which lies just beneath the ambulacral ring canal, and five **radial nerves**, which proceed from it along the median line of the ambulacral grooves to the tips of the arms. Each radial nerve ends with a **pigment eye**. There are no other organs of special sense. The main nerves of the starfish do not lie within the body cavity but in the integument and can thus be seen from the outside. There are, however, in addition to these nerves, other less important ones which are internal. We have already observed the radial nerves in the median line of the ambulacral grooves; the ring nerve can also be seen as a slight ridge just beneath the ring canal.

Exercise 8. Draw a diagram representing the nervous system.

Exercise 9. Draw a diagram representing a vertical section of the animal passing through the madreporite and the anterior ray (that is, the middle trivial ray).

CLASS: *Echinoidea*

A SEA URCHIN

Several species of sea urchins occur along the Atlantic coast, the most familiar being Arbacia, the dark-colored urchin, and Strongylocentrotus, the green urchin, the former having a more southerly distribution than the latter. The animals live on the sea bottom or on rocks, usually in companies, and move slowly about from place to place, using not only the ambulacral feet but often the spines as well, as organs of locomotion. They feed partly upon small animals and partly upon organic substances present in the sand and mud, which they pass through the intestine.

Two specimens will be needed for this dissection, a dried one for the study of the hard parts and a fresh or preserved one for the study of the internal organs.

Observe the radiate, spheroidal body entirely covered with movable spines. Look among the spines and find the **ambulacral feet.** These can be extended in life beyond the spines and are employed by the animal as organs of locomotion. Note the five **ambulacral areas** (those containing the feet), and between them the five **interambulacral areas.** The flattened surface is the under, or **oral, surface,** on which the animal moves; the rounded surface is the **aboral.** It will be seen that the aboral side of the sea urchin bears ambulacral feet, whereas in the starfish the oral side alone bears them.

In the center of the oral surface observe the **mouth** and the five calcareous **teeth** which project from it. Surrounding the mouth is a membrane which fills the space between the edges of the shell and is called the **peristome.** Notice the ten short **ambulacral suckers** which surround the mouth, and near them the five groups of pincer-like **pedicellariæ.** Observe the long, slender **stalks** of these organs. Near the margin of the peristome are five groups of **ambulacral feet,** which are in the ambulacral areas, and also ten groups of short branched **gills,** which mark the interambulacral areas.

Exercise 1. Make a drawing of the oral surface on a scale of 2.

With forceps remove some of the pedicellariæ, mount them, and study them under the microscope. Note the three minute jaws and the long stalk. Press on the cover glass and cause the jaws to open and shut.

Exercise 2. Make a drawing of a pedicellaria.

Study the structure and method of articulation of the spines. Pull off several and notice their ball-and-socket joints, also the delicate muscles by which they are moved. Notice the fluting of the shaft.

Exercise 3. Make a semidiagrammatic drawing of a spine on a large scale, showing the articulation of the muscles.

Remove the spines from the dried specimen and thoroughly clean the shell. This is accomplished the most effectually by placing it in a solution of warm caustic potash for a short time. Great care should be taken, however, not to leave it in the solution too long or it will fall to pieces. Study the aboral side of the shell. Observe the rows of tubercles on which the spines have articulated; note also the bands of minute holes, the **ambulacral pores**, through which the ambulacral feet have projected. There are ten of these bands arranged in pairs, and each pair represents an ambulacral area, or a ray. Between the five rays are the five interambulacral areas, or the interrays, which are somewhat broader than the rays; count the rays and the interrays.

The center of the aboral surface is free from spines and is made up of several small plates. It is called the **periproct** and contains in its center the minute **anus**. Surrounding the periproct are ten plates, which also bear no spines. Five of these, which are larger than the others, are situated at the ends of the interrays and are pierced each by a small hole. These plates are called the **genital plates,** and the holes are the external openings of the genital organs. One of the genital plates is larger than the others and is porous; it is the **madreporite**. The five smaller of the ten plates which surround the periproct are situated at the ends of the rays. They are called the **ocular plates**. Each is pierced by one or two

holes, through which project minute, pigmented tentacles. Notice that each ray and each interray is made up of two rows of plates; thus there are twenty rows of plates altogether. As in the starfish, the two rays between which the madreporite lies are called the **bivium**; the other three, the **trivium**.

Exercise 4. Make a drawing of the aboral side of the shell, with the spines removed, on a scale of 2, showing accurately the boundaries of all the plates. Label the rays, interrays, and all the other parts observed.

The Internal Organs. Place a fresh or preserved sea urchin in a pan of water. Carefully cut away the peristome with scissors and remove the shell of the oral body wall on one side of the peristome without disturbing the organs within. Observe the following systems of organs:

The Digestive System. This is quite different from the same system in the starfish. The mouth opens into the **œsophagus**, which passes through the center of the large, cone-shaped **dentary apparatus**, which is also, because of its shape, called **Aristotle's lantern.** This is a complicated structure consisting of a number of calcareous plates and muscles which project from the mouth into the body cavity. Study its muscular attachment with the shell. Note the **protractor muscles**, which pass from its upper end to the oral body wall, by means of which the apparatus can be thrust down and partly out of the mouth; note also the **retractor muscles**, which pass from the lower part of it to the tall inner projections of the shell.

Exercise 5. Draw a diagram showing the dentary apparatus in the body and its muscular attachment to the shell.

The **œsophagus**, after leaving the dentary apparatus, passes to the elongated **intestine**; this lies close to the body wall, to which it is attached by means of a **mesentery**. Carefully follow the intestine, breaking away the wall if necessary, as it winds around the inner surface of the shell. Note the **intestinal siphon**, a short tube which lies alongside the intestine, joining it at both ends. From the intestine a short **rectum** passes to the **anus**. In making this dissection keep the animal immersed in clear water;

remove as little of the shell as possible, and do not remove any of the organs from the body.

The **genital system** is similar to that in the starfish. The sexes are separate, but the **sexual glands** of the male and female are alike in appearance. They consist of five radial, granular masses, which lie in the upper part of the body cavity, each mass communicating with the outside through one of the genital pores. The actual extent of the sexual glands depends upon the sexual condition of the animal. During the breeding season, in the summer, they may almost fill the body cavity.

Exercise 6. Make a diagrammatic drawing of the digestive and reproductive systems and label all their parts.

Remove the dentary apparatus from the body and examine it carefully. It is made up principally of five triangular plates called **alveoli**, the lower ends of which bear the **teeth**. The alveoli are bound together by short muscles. The base of the dentary apparatus is made up of a complicated system of smaller plates.

Exercise 7. Make a drawing of the dentary apparatus.

The **ambulacral system** is similar to that of the starfish. A **ring canal** surrounds the œsophagus just inside the inner end of the dentary apparatus and is connected with the madreporite by means of the **stone canal**. This organ is a small tube which lies in contact with the œsophagus and also, in the neighborhood of the aboral body wall, with the rectum. From the ring canal five **radial canals** pass along the median lines of the rays to their aboral ends, sending off branches to the **ambulacral feet**. The entire system of tubes, except the ambulacral feet, is within the body cavity, instead of outside it, as in the starfish. Look on the inner surface of a ray for the radial canal. On each side of it observe the row of small vesicles, the **ampullæ**, which are the reservoirs of the ambulacral feet. Determine the exact relation of the ampullæ to the feet, and of both to the ambulacral pores in the shell. It will be seen that there are two rows of these latter on each side of the radial canal. Through one of these rows the branch canals pass from the radial canal to the ambulacral feet on the outside of

the shell; through the other row projections of the feet pass back into the body cavity, where they expand to form the ampullæ. There is thus a single row of feet on each side of the radial canal in each ray.

The ambulacral system will be seen to consist of a system of tubes extending throughout the body and communicating with the sea water through the madreporite. It is filled with a fluid which, as in the starfish, is not pure sea water, but is rather a watery serum in which float amœboid cells. This fluid can be driven into the ambulacral feet, which acquire rigidity and are thereby extended. The animal moves by extending the feet, attaching the sucker disks at their ends to some stationary object, and then drawing them in; it is able thus to pull itself slowly along. Some sea urchins with long spines also move on the tips of their oral spines as on stilts.

Exercise 8. Draw a diagram representing the ambulacral system.

Respiration and excretion are performed by the peristomial gills and the ambulacral feet.

The **nervous system** cannot be studied in a dissection. It is essentially like that of the starfish. From the ring nerve around the œsophagus five radial nerves pass along the median line of the rays to the ocular plates, where each terminates in a tentacle. The entire system is within the body cavity instead of a portion of it being outside as in the starfish.

CLASS: *Holothurioidea*

A SEA CUCUMBER

Two common species of holothurians which live in the shallow water of the New England coast are suitable for this dissection: *Thyone briareus* and *Cucumaria frondosa*, the former being common in Vineyard and Long Island Sounds, and the latter on the Maine coast. The latter is the larger of the two species, being from ten to twenty-five centimeters or more long and about half as thick, and differs from Thyone, among other things, in having ambulacral feet in the radial areas alone; thus it possesses five broad bands of these appendages, the interradial areas being smooth. Thyone is from eight to about twenty centimeters long and five centimeters thick, and is covered with ambulacral feet, the five broad radial bands meeting in the interradial areas. It will be used as the basis of this dissection.

Observe the form and color of the **body**. Note that the upper and lower sides are distinctly differentiated, the former having fewer feet than the latter. In the center of the forward end is the **mouth**, surrounded by ten branched **tentacles**, by means of which the animal collects the minute organisms which constitute its food. Above the mouth and between the bases of two tentacles is the **genital pore**. In the center of the hinder end is the **anus**, surrounded by five **anal teeth**. The main longitudinal axis of the body (that which joins the mouth and the anus) will thus be seen to be very long, in sharp contrast to that of the starfish and sea urchin, in which it is much shorter. In consequence of this feature the body is elongate and more or less wormlike, and the animal does not rest on the oral surface but on its side.

Exercise 1. Draw a side view of the animal and label carefully all the features observed.

With strong scissors cut the body open by a longitudinal slit along the underside. Place it in a pan of water and with large pins fasten down the two sides of the body wall on the right and left. Without cutting any of them, study the internal organs.

Note the spacious body cavity and the long, coiled intestine which partly fills it. At the front end of the body and just behind the tentacles is the conspicuous **calcareous ring**, a more or less rigid cylinder containing five radial and five interradial plates, which surrounds the œsophagus. Projecting from the hinder end of the calcareous ring will be seen two large, cylindrical sacs, the **Polian vesicles**, and inserted in the ring are five prominent **retractor muscles**, by means of which the tentacles and the forward end of the body can be invaginated. Note the position of the **genital gland** and its **duct**. The gland is a thick bunch of slender filaments in the forward part of the body cavity, joined with the body wall by a mesentery, which converge to the hinder end of the duct. This is a slender tube which passes forward on the upper side of the body cavity and opens to the outside between two tentacles on the upper side of the body. The sexes are separate; they are alike, however, in appearance. Note the **respiratory trees**, the profusely branched organs which extend from the rectum throughout the entire length of the body cavity.

Study the course of the **digestive tract**. The **œsophagus** passes through the calcareous ring to the thick-walled, muscular **stomach**, which lies directly behind it. From the hinder end of the stomach the long, thin-walled **intestine** passes, with many loops and turns, to the short, wide **rectum** at the hinder end of the body. Trace the intestine carefully, but without cutting it, throughout its entire course and note the three mesenteries by which it is attached to the body wall.

Note the thick, muscular walls of the rectum and the **muscle strands** which join it with the body wall. The two branching respiratory trees spring from the forward end of the rectum and extend through the body cavity to its forward end. Observe carefully their extent. It is by the periodic dilation and contraction of the muscular walls of the rectum that water is alternately taken into the rectum and the respiratory trees and expelled from them, and respiration thus carried on.

Exercise 2. Draw a diagrammatic view of the opened animal on a large scale, showing the organs observed. Carefully label all.

Cut the œsophagus just back of the calcareous ring and remove the digestive tract with the respiratory trees and the genital gland from the body. The five **retractor muscles** of the calcareous ring may be followed to the body wall, where they will be seen to join five **longitudinal muscles** which extend along the inner surface of the body wall the length of the body. These muscles mark the five radial areas of the body. Note the **circular muscles** which also lie on the inner surface of the body wall.

Study the **ambulacral system.** The **ring canal**, which is often difficult to see, surrounds the œsophagus at the hinder end of the calcareous ring. The **Polian vesicles**, two elongated sacs which have already been noted, extend from it into the body cavity. They secrete and store the lymphatic fluid which fills the ambulacral canals. The **stone canal**, which also extends from the ring canal, is a slender tube, and the **madreporite** with which it ends lies in the body cavity and not at the surface of the body. It is probably a rudimentary structure. The five **radial canals** extend from the ring canal along the radial areas of the body and beneath the five radial **muscle bands** to the hinder end of the body. The **ambulacral feet** extend from the radial canals through the body wall and are seen thickly studding the outer surface of the body. The numerous **ampullæ** extend into the body cavity and will be seen on the inner surface of the body wall. The **tentacles** are also a part of the ambulacral system, the canals which supply them with the ambulacral fluid springing from the radial canals.

Exercise 3. Draw a diagram of the ambulacral system.

Exercise 4. Draw a diagram representing an ideal cross section through the middle of the body.

The **calcareous spicules** and **plates** which form a part of the body wall and are so characteristic of the echinoderms as a group are less conspicuous in holothurians than in any of the other classes of the phylum, and will not be studied in this dissection. They are of minute size, although definite in shape in the various species, and do not form a connected skeleton as in the starfish and the sea urchin. Pedicellariæ are absent.

PHYLUM CŒLENTERATA

CLASS: *Hydrozoa*

HYDRA

This small animal is of general although sporadic distribution throughout the country. It frequents ponds and streams abounding in plant life and is best obtained by collecting water together with water plants, sticks, and other objects from several such places, and allowing it to stand in glass jars. The polyps will, if present, be seen, after an interval of some time, attached to the stems or leaves of the plants or to the sides of the jar. They may be kept indefinitely in aquaria of this sort and will usually multiply rapidly. Three species of Hydra are common in this country: the brown or reddish hydra (*Hydra oligactis*), which has tentacles much longer than the body, the green hydra (*Hydra viridissima*), and the gray hydra (*Hydra vulgaris*), both of the latter species having relatively short tentacles.

Hydra is a slender, tubular animal from one eighth to one half an inch in length; it attaches itself by one end to some stationary object and projects pendant in the water; at the other end is the **mouth**, surrounded by from four to eleven long, thread-like **tentacles**. It does not attach itself permanently to one place, but can crawl about or swim slowly through the water. Its food consists largely of small crustaceans which it kills or paralyzes with the peculiar stinging organs called **nettle cells**, located principally in the tentacles.

Study the animals first, if possible, without disturbing them and with the aid of a hand lens. Note the extreme contractility of the body. Look for individuals with distended bodies. These have just swallowed prey. Look for budding individuals; budding is one method of reproduction. Observe the color of the animal.

Detach a polyp by means of a pipette, place it in a watch glass of water, and study it under a microscope.

Exercise 1. Draw several outlines of the animal on a large scale, showing different shapes and positions it can assume. Notice the mouth in the midst of the tentacles.

Place a polyp on a slide in water and cover it with a cover glass, but support the corners of the latter with wax to avoid crushing the animal. Study its structure under the microscope. We see that the type of structure is radial and not bilaterally symmetrical; that the animal is tubular in shape, and that its internal cavity opens to the outside through the mouth; that the **mouth** is a small opening at the end of the conical, terminal portion of the body, called the **hypostome**, at the base of which are the tentacles. The internal cavity is called the **gastrovascular space** and is the common digestive and circulatory cavity of the animal. The end by which the animal is attached is called the **foot**. It is an adhesive disk containing gland cells which produce a sticky secretion.

Examine the finer structure under a high power of the microscope. The body wall is made up of two layers of cells, the outer **ectoderm** and the inner **entoderm**. The cells of the latter are much longer and more irregular than those of the ectoderm; their inner surfaces are amœboid and also often flagellate. Embedded in the entoderm cells are the **chromatophores**, the bodies which give color to the animals. In the green hydra these are chlorophyll bodies; in the brown hydra they consist of a substance similar to chlorophyll. In both cases they are probably single-celled algæ living symbiotically with the polyp. Between these two cell layers is a thin noncellular one called the **supporting layer.** The tentacle is a hollow projection of the body wall and has the same structure.

Among the ectoderm cells of the distal portion of the body, and especially of the tentacles, notice the oval, highly refractive stinging organs, or **nematocysts**. Each one consists of a spiral, thread-like tube, with several barbs at its base, which lies coiled within the cavity of a cell called a **cnidoblast**. The cavity is filled with a

poisonous fluid; its walls form an ovoid sac, of which the tube is the very much elongated and invaginated outer end. A minute spine projects beyond the free surface of the cnidoblast into the water. When the surface of the ectoderm is irritated the tube is evaginated and shot violently out, and the poisonous fluid contained in the cavity of the nematocyst is injected into any animal that may be struck.

Exercise 2. Make a large semidiagrammatic drawing of the animal showing the details of its structure; label all carefully.

Methods of Reproduction. Hydra reproduces both sexually and asexually. Well-fed polyps will soon begin to bud off new individuals. The bud makes its appearance first as a projection of the body wall, and soon becomes a distinct branch. Tentacles and a mouth make their appearance at the extremity of the branch, and the young polyp is complete. It remains attached to the parent for a while; then detaches itself and begins an independent life.

Besides this asexual method of reproduction, which may go on as long as the animal is well fed and vigorous, reproduction by sexual methods also occurs at more or less irregular intervals. **Sexual organs** appear in the form of projections of the ectoderm of the body wall. Two classes of these projections appear: smaller ones, which are **testes**, and larger ones, which are **ovaries**. The former of these organs, which lie near the distal end of the animal, produce spermatozoa; the latter are near the proximal end, and each produces a single large ovum. The green hydra is a hermaphroditic animal, having both testes and ovary when sexually active, whereas the brown hydra is diœcious, being either male or female.

Exercise 3. Find a polyp with reproductive organs and make a drawing of it.

Special respiratory, excretory, digestive, and circulatory organs are absent in the hydra. **Respiration** and **excretion** are carried on through the surface of the body wall. **Digestion**, **circulation**, and **absorption** go on within the gastrovascular space. The animal's prey is caught in the water with the tentacles, which sting it into

insensibility, and then swallowed into the gastrovascular space. The entoderm cells, which line this cavity, extend their very plastic inner ends toward or about it, and some of them secrete a digestive fluid. The object is then digested and mingles with the water present in the gastrovascular space, while by the vibrations of the flagella currents are produced which cause this fluid to circulate throughout all the parts of it.

Distinct muscular and nervous systems are absent in the hydra. Delicate **muscle fibers** are present, however, in the form of long, parallel projections of the inner ends of ectoderm cells. Nervous elements are also present in the form of isolated **ganglionic cells** situated in the ectoderm, which send delicate projections to the muscle fibers and to the nematocysts. Both muscle fibers and ganglion cells are present throughout the animal's body but are most numerous in the tentacles. There are no organs of special sense.

CLASS: *Hydrozoa*. ORDER: *Anthomedusæ*

A TUBULARIAN HYDROMEDUSAN (*PENNARIA*)

Pennaria is a marine animal and one of the commonest hydromedusans along our coast. As is characteristic of the group to which it belongs, it exhibits the phenomenon of **alternation of generations**. Two generations of individuals, a sexual and an asexual, alternate with each other. The latter is called the **hydroid generation**; the animal in this stage is sessile and colonial, and produces by budding, that is, by asexual methods, the sexual generation. This is called the **medusoid generation**; in it the animal either remains attached to the hydroid colony and is then called a **sporosac**, or separates itself and becomes a free-swimming jellyfish, which is called a **medusa**; in either case the medusoid produces by sexual methods embryos which, after a brief free life, attach themselves to fixed objects and develop into the hydroid generation.

The Hydroid Stage in Pennaria.[1] In this stage these animals form branching colonies of polyps, which are attached to the rocks and seaweed in shallow water. The colonies are several inches in length, and are found in thick clusters which often cover the rocks over small spaces; their color is a delicate pink.

Place a small portion of a colony in a watch glass of water or alcohol, and study it under the microscope. Observe the main stem of the colony and its branches, also the position of the **polyps** on the branches. Note carefully the differences in size between the different polyps. Which is the largest polyp? Study the method of branching. Has the colony a main axial stem? If it has, the oldest polyp will be the one at the tip of the stem and the second oldest will be the one at the end of the lowest branch.

The stem of the colony together with the branches is called the **hydrocaulus**; the rootlike projections by which it is attached at its base are the **hydrorhiza**; the polyps are called **hydranths**.

[1] Bougainvillea or any other tubularian can also be used, with slight changes in the directions.

Exercise 1. Draw a diagram representing the method of branching and showing the arrangement of the polyps on the stem.

Mount a small branch of the colony on a slide in water and study a number of hydranths of all sizes. Note the radial type of structure and the tubular body, the internal cavity of which opens to the outside through the small terminal **mouth**. The stem also and its branches have an internal cavity which is a continuation of that of the hydranth. The cavity of the hydranth and the stem is called the **gastrovascular space** and is the common digestive and circulatory cavity of the animal. Notice the ringed constrictions in various parts of the stem, especially near the polyps; they give the stem strength and flexibility.

Study the two kinds of **tentacles**, the whorl of larger ones around the base of the hydranth and the shorter ones on the body of it. In Bougainvillea the basal tentacles alone are present. Count the basal tentacles. Count the short tentacles on a large and then on a small hydranth. The larger hydranth will be found to have more than the smaller one. Notice the small **hydranth buds** on the side of the stem; find one whose tentacles have not yet developed. Some of the hydranths will be seen to have large ovoid projections of variable size on their sides. These are the **medusoid buds**, which become either free-swimming medusæ or sessile sporosacs. In Bougainvillea the medusoid buds do not appear on the hydranths but on the stem; they become free-swimming medusæ.

Exercise 2. Make a semidiagrammatic sketch of a large hydranth and a portion of the stem on a large scale; label the different parts.

Exercise 3. Make a sketch on a large scale of the smallest hydranth or hydranth bud you can find.

Mount a hydranth and a part of the stem on a slide in dilute glycerine, and study their finer structure. First study the structure of a tentacle. It is not hollow as is the tentacle of Hydra, but is made up of an axis consisting of a single row of large **entoderm cells** around which is a layer of small **ectoderm cells.** Between these two cell layers is the delicate, noncellular **supporting layer.** Find the highly refractive stinging organs, or **nematocysts,** at the end of the tentacle. These are the organs with which the

animal kills its prey. Each one consists of a spiral, threadlike tube, with several barbs at its base, which lies coiled within the cavity of a cell called the **cnidoblast.** The cavity is filled with a poisonous fluid; its walls form an ovoid sac, of which the tube is the very much elongated and invaginated outer end. A minute spine projects beyond the free surface of the cnidoblast into the water. When the surface of the ectoderm is irritated the tube is evaginated and shot violently out, and the poisonous fluid contained in the cavity of the nematocyst is injected into any animal that may be struck. Look for nematocysts which have discharged their spiral threads.

Exercise 4. Draw the distal portion of a tentacle showing its cellular structure; show the nematocysts at the end, including several which have been discharged.

Study the structure of the wall of the hydranth. It is made up of an outer **ectoderm** and a much thicker inner **entoderm**, each composed of a single layer of cells; the inner ends of the entoderm cells are amœboid and often flagellate, the function of the flagella being to maintain in circulation the fluids in the gastrovascular space; between these two layers is the thin, noncellular **supporting layer.** Study the structure of the stem. Observe its central cavity, which is a part of the gastrovascular space, and the three layers just mentioned. In live specimens notice the action of the flagella. Notice the cuticula which covers the outer surface; it is not found in the hydranth. This cuticula is called the **perisarc.** It is a supporting structure and gives the colony rigidity.

Exercise 5. Make a drawing showing the cellular structure of the wall of the hydranth and of the stalk so far as observed; carefully label all.

Special respiratory, excretory, digestive, and circulatory organs are not present in the hydroid. **Respiration** and **excretion** are carried on through the surface of the body wall. **Digestion, circulation**, and **absorption** go on within the gastrovascular space. The polyps feed upon small swimming animals, which they kill or stun with their nematocysts and then swallow into

the gastrovascular space. Digestion goes on within this space, and waste matters are ejected from the mouth. The products of digestion mingle with the water present in the gastrovascular space and circulate throughout the colony, the internal cavities of all the individual polyps of a colony being in communication with one another. When a colony is well fed it grows rapidly, new hydranths bud out from the stalk, and medusoid buds appear and grow into medusæ. The hydranths are frequently destroyed by frost or by the beating of waves or by fishes, but new ones quickly grow in their places.

The Medusoid Stage. The medusoids of tubularian hydromedusans are either sessile **sporosacs** or free-swimming **medusæ.** Pennaria produces both kinds. During a greater part and in some cases the whole of the year they remain attached to the colony and are thus sporosacs, but usually during the middle and last of the summer they detach themselves from the hydroid and become free-swimming medusæ. Both conditions may be found in the same colony and at the same time. The medusoids of Bougainvillea are always free-swimming and with other medusæ will be found in the surface waters of the ocean. They may usually be easily obtained by placing the live hydroid colony in a small glass of sea water; the medusæ will be found swimming about in the water.

Place several medusæ of Bougainvillea or of any other tubularian in a watch glass of sea water or, if they are preserved specimens, in alcohol. If they are alive, observe the swimming motions. Note the radiate type of structure. The body is bell-shaped, having an outer convex and an inner concave side, and on its margin are **tentacles** (in the medusa of Pennaria they are rudimentary). The convex side is called the **exumbrella** or **aboral side**, and the concave, the **subumbrella** or **oral side.** In the center of the latter is the proboscis-like projection called the **manubrium**, at the distal end of which is the **mouth**, surrounded by short **oral tentacles.** The mouth opens into the **gastrovascular space**, which comprises the space within the manubrium and also a system of canals in the bell-shaped body. These canals consist of four **radial tubes**, which extend from the base of the manu-

brium to the periphery of the body, and are there united by a **circular tube**, which runs parallel with the margin and close to it.

Observe the arrangement of the marginal tentacles, and also of the oral tentacles, if these are present. At the base of the groups of marginal tentacles are minute sense organs, the **ocelli**; they are characterized by the presence of pigment and are sensitive to light. Note the four swellings on the side of the manubrium; these are the **sexual organs** and are specialized portions of the ectoderm. The sexes are separate. Around the inner margin of the subumbrella, at the base of the tentacles, is a broad, muscular membrane extending inward and called the **velum**, by means of which the animal swims.

Exercise 6. Make a diagrammatic sketch of the medusa as far as observed and label all its parts.

The medusa is a more highly specialized form than the polyp, although they are homologous forms and are essentially alike in structure. The different vegetative functions are carried on in the medusa as they are in the hydranth. The medusa being a free-swimming animal, however, its muscular and nervous systems are much more highly developed than the same systems are in the hydranth. In the latter the only muscles present are delicate fibers, elongated projections of the inner ends of ectodermal cells, which cause movement in the tentacles and the body of the hydranth, and the nervous system is represented only by scattered ganglion cells, which lie among the ectoderm cells. In the medusa the **velum** is the principal organ of locomotion. It contains bands of ectodermal **muscle fibers**, by the contraction of which the motion of the umbrella is produced which propels the animal through the water. The **nervous system** consists of a double **nerve ring** of ganglion cells and fibers running around the margin of the disk, from which delicate fibers run to the velum and to the sense organs.

CLASS: *Hydrozoa*. ORDER: *Leptomedusæ*

A CAMPANULARIAN HYDROMEDUSAN (*OBELIA* OR *CAMPANULARIA*)

These are very common marine animals which live in the shallow water along our coast. In common with other members of the group they exhibit the phenomenon of **alternation of generations**. Two generations of individuals, a sexual and an asexual, alternate with each other. The latter is called the **hydroid generation**; the animal in this stage is sessile and colonial and produces by budding, that is, by asexual methods, the sexual generation. This is called the **medusoid generation**; in it the animal either remains attached to the hydroid colony (Campanularia) and is then called a **sporosac**, or separates itself (Obelia) and becomes a free-swimming jellyfish, which is called a **medusa**; in either case the medusoid produces by sexual methods embryos which, after a brief free life, attach themselves to fixed objects and develop into the hydroid generation.

The Hydroid Stage. While in this stage these animals form branching colonies, which are attached to seaweed, rocks, and other objects. Place a small portion of a colony in a watch glass in water or alcohol, and study it under the microscope. Observe the differences in size between the different polyps, as well as their position on the stem. Determine the method of branching. Has the colony a main axial stem? If not, which is the oldest polyp? Notice the ringed constrictions in various parts of the stem, especially near the polyp; they give the stem strength and flexibility.

The stem of the colony together with the branches is called the **hydrocaulus**; its rootlike projections by which it is attached at its base are the **hydrorhiza**. Observe that there are two distinctly different kinds of polyps instead of but one, as in Pennaria or Bougainvillea: (1) the **feeding polyp**, or **hydranth**, which is the more numerous and bears tentacles, and (2) the **reproductive polyp**, or **blastostyle**, which is a modified hydranth and is much the larger and the less numerous and bears no tentacles. Notice that the **perisarc**, the transparent cuticular covering of the stem,

does not end at the base of the polyp, as is the case in the tubularian hydroid, but is continued over the polyp, inclosing it as in a cup. It is thus a protective device and is called in the case of the hydranth the **hydrotheca**, and in the case of the blastostyle the **gonotheca**. The feeding polyp withdraws within its hydrotheca for protection when alarmed. The reproductive polyp never emerges from its gonotheca, which is a closed structure, but the medusoids or their sexual products escape into the surrounding water through an opening in the gonotheca's free end.

Exercise 1. Draw a diagram representing the method of branching of the colony and the arrangement of the polyps.

Mount a portion of a branch with several hydranths in water or dilute glycerine. Study an expanded hydranth. We note the radial type of structure and the tubular body, the internal cavity of which opens to the outside through the terminal **mouth**; also that the stem has a cavity which is continuous with that of the hydranth. The internal cavity of the hydranth and of the stem is called the **gastrovascular space** and is the common digestive and circulatory cavity of the animal. The portion of the hydranth between the base of the tentacles and the mouth is called the **hypostome**. Count the **tentacles**.

Exercise 2. Make a semidiagrammatic sketch of the expanded hydranth on a large scale and label all its parts.

Exercise 3. Make a sketch of a contracted hydranth.

Study the finer structure of an expanded hydranth. First study the structure of a tentacle. It is made up of an axis consisting of a single row of large **entoderm cells**, around which is a layer of small **ectoderm cells**. Between these two cell layers is the delicate, noncellular **supporting layer**. Find the highly refractive **nematocysts** in the tentacle. These are the stinging organs with which the animal kills its prey. Each one consists of a spiral, threadlike tube, with several barbs at its base, which lies coiled within the cavity of a cell called the **cnidoblast**. The cavity is filled with a poisonous fluid; its walls form an ovoid sac, of which the tube is the very much elongated and invaginated outer

end. A minute spine projects beyond the free surface of the cnidoblast into the water. When the surface of the ectoderm is irritated the tube is evaginated and violently shot out, and the poisonous fluid contained in the cavity is injected into any animal that may be struck. Look for nematocysts which have discharged their spiral threads.

Exercise 4. Draw the distal portion of a tentacle showing its cellular structure; show the nematocysts at the end, including several which have been discharged.

Study the finer structure of the wall of the hydranth. It is made up of an outer **ectoderm** and a much thicker inner **entoderm**, each composed of a single layer of cells; the inner ends of the entoderm cells are amœboid and often flagellate, the function of the flagella being to maintain in circulation the fluids in the gastrovascular space; between these two layers is the thin noncellular **supporting layer**. The **hydrotheca** incloses all, but it is not in contact with the ectoderm. Study the structure of the stem; it has essentially the same structure as the hydranth; note the outer cuticular covering, the **perisarc**. Note the action of the flagella in a live specimen.

Exercise 5. Make a drawing showing the cellular structure of the wall of the hydranth and of the stem.

Study a **blastostyle**. We note that it is a cylindrical object inclosed within its transparent **gonotheca**. Budding out on the sides are the young disk-like **medusæ**, those toward the free end being the largest and the oldest. The blastostyle has no tentacles and no mouth. It has an internal cavity which is a part of the gastrovascular space of the colony, and within which the nutritive fluids circulate.

Exercise 6. Make a drawing of a blastostyle.

Special respiratory, excretory, digestive, and circulatory organs are not present in the hydroid. **Respiration** and **excretion** are carried on through the surface of the body wall. **Digestion**, **circulation**, and **absorption** go on within the gastrovascular space. The

colony lives upon small swimming animals, which the feeding polyps kill or stun with their nematocysts, and then swallow into the gastrovascular space. Digestion goes on within the feeding polyps; the products of digestion mingle with the water present in the gastrovascular space and circulate throughout the colony. The entire colony is thus nourished, and if conditions are favorable it will grow rapidly and produce a large number of medusæ. The polyps are frequently destroyed by frost or by the beating of waves or by fishes, but new ones quickly grow in their places.

The Medusoid Stage. The medusoids of campanularian hydromedusans are either sessile sporosacs or free-swimming medusæ. The medusæ are minute disk-shaped jellyfishes, about one eighth of an inch in diameter, which may be found swimming in the surface waters of the ocean. Place several in a watch glass of sea water or, if they are preserved specimens, in alcohol. If they are alive, observe the swimming motions. Note the radiate type of structure. The body resembles an umbrella in shape, having a convex and a concave side, and is bordered by a fringe of **tentacles**. The former is called the **exumbrella** or **aboral side**, the latter, the **subumbrella** or **oral side**. In the center of the latter side is the proboscis-like projection called the **manubrium**, at the distal end of which is the **mouth**. This opens into the **gastrovascular space**, which comprises the space within the manubrium and also a system of canals in the disk-like body. These canals consist of four or more **radial tubes**, which extend from the base of the manubrium to the periphery of the disk, and are there united by a **circular tube** which runs parallel with the margin of the disk and close to it.

Count the marginal tentacles. At the base of certain of the tentacles are minute sense organs, called **lithocysts**, which are probably organs of equilibrium. Find them.

Near the middle of each radial tube notice a prominent swelling on the subumbrella. These are the **sexual glands** and are specialized portions of the ectoderm. The sexes are separate in medusæ, but the sexual glands have the same appearance in the two sexes.

Around the inner margin of the subumbrella, at the base of the tentacles, is a muscular membrane extending toward the manu-

brium and called the **velum**, by means of which the animal swims. In campanularian medusæ it is often very narrow and not easily seen; in tubularian medusæ it is broad and very noticeable.

Exercise 7. Make a diagrammatic sketch of a medusa and label all its parts.

The medusa is a more highly specialized form than the polyp, although they are homologous forms and are essentially alike in structure. The manubrium of the medusa and the hypostome of the polyp do not differ essentially from each other; the tentacles are also homologous structures. Consequently the exumbrella of the medusa corresponds to the base of the polyp, and just as the latter is attached to the stem at its base, so the medusa is attached to the blastostyle by its exumbrella. The digestive, excretory, respiratory, and circulatory functions are carried on in the medusa as they are in the hydranth. But because the medusa is a free-swimming animal, its muscular and nervous systems are much more highly developed than are the same systems in the hydranth.

In the latter form the only muscles present are delicate fibers, elongated projections of the inner ends of ectodermal cells, which cause movement in the tentacles and the body of the hydranth, and the nervous system is represented only by scattered ganglionic cells, which are also of ectodermal origin. In the medusa the **velum** is the principal organ of locomotion. It contains bands of ectodermal **muscle fibers**, by the contraction of which the motion of the umbrella is produced which propels the animal through the water. The **nervous system** consists of a double **nerve ring** which runs around the margin of the disk and from which delicate fibers pass to the velum and the sense organs.

CLASS: *Hydrozoa*. ORDER: *Trachomedusæ*

A MEDUSA (*GONIONEMUS*)

This animal is a better form to study, on account of its larger size, than the minute tubularian or campanularian jellyfish. It is a very common medusa at Woods Hole, but its range of distribution is very limited, although it has also been found in Long Island Sound.

Place the medusa in a small dish of water, which should be set upon a dark background. The water should be deep enough to permit the jellyfish to be readily turned over. If it is alive, study the pulsations of the bell, by means of which it swims. With a simple lens or a compound microscope study its form and color. Note the radiate type of structure. Unlike the bilaterally symmetrical animals, the medusa has no dorsal, ventral, anterior, or posterior side.

The outer, convex surface of the bell-shaped body is called the **exumbrella** or the aboral side, and the concave underside is called the **subumbrella** or the oral side. From the center of the latter extends a large, dark-brown projection called the **manubrium**, at the distal end of which is the **mouth**, surrounded by four recurved **lips**. At the base of the manubrium is the **stomach**, a four-sided sac from the four corners of which the four straight **radial canals** extend to the periphery of the body, where they are united by the **ring canal**, which runs around the margin of the bell. The radial and ring canals, together with the stomach and the cavity of the manubrium, form the **gastrovascular space**, the entodermal lining of which is colored brown.

Directly beneath the four radial canals and projecting slightly into the subumbrella space are the four **reproductive organs**, which are also brown in color and present a corrugated appearance. The sexes are separate, but the animals are not dimorphic.

Observe the number and arrangement of the **tentacles**, of which an adult medusa possesses from sixty to eighty. Note the spiral arrangement of the **nettle cells** on each tentacle, and also the **adhesive pad** near its outer end. It is by means of the nettle cells in

these pads that the animal anchors itself to seaweeds and other objects when at rest. Note the exact point above the margin of the bell where the tentacles are inserted. In the basal portion of each tentacle is a conspicuous, pigmented body; this is a hollow bulb which is connected with the ring canal. Between the tentacles are the **lithocysts**, minute projections from the margin of the bell which are probably equilibrial in function.

Observe the **velum**, the membrane which extends around the inner margin of the bell toward the manubrium. It is the principal organ of locomotion and contains bands of ectodermal muscle fibers by the contractions of which the motion of the bell is produced which propels the animal through the water. Similar bands of muscle fibers are also present in both the subumbrella and the exumbrella.

Exercise 1. Draw a semidiagrammatic view of the exumbrella on a scale of from 5 to 10, showing the tentacles extended and all the organs which have been observed.

Exercise 2. Draw a side view of the animal on the same scale, showing the velum, the manubrium, and all the other organs observed.

Exercise 3. Draw a semidiagrammatic view of the subumbrella on a scale of 5 to 10, showing the velum, the manubrium, and the other organs observed.

The hydroid generation of Gonionemus is a minute, solitary polyp which lives attached to the bottom in shallow water; it will not be studied here. The polyp is only about one millimeter in height and has four tentacles which can be extended two millimeters. It is thus very much smaller than the medusa, which has a height of about nine millimeters and a diameter of about twenty. The polyp forms new polyps by budding, but has never been observed forming the medusæ; so it is not known how these originate.

CLASS: *Anthozoa*. ORDER: *Zoantharia*

A SEA ANEMONE (*METRIDIUM*)

This animal, which is the largest sea anemone along the North Atlantic coast, is often plentiful on rocks, shells, and docks in shallow water. Place an expanded individual in a deep dish of water and observe its shape, color, and method of attachment. The upper end of the columnar body is called the **disk**; in its center is the elongate, slitlike **mouth**, surrounded by the numerous **tentacles**. The lower end of the animal is called the **foot**. It is not permanently attached to the substratum; the animal has some locomotory powers and can slowly move from place to place.

Study the form of the mouth. Note the thickened lips at each angle of the mouth; these form a ciliated groove, called the **siphonoglyph**, through which the genital products reach the outside. In some individuals only one siphonoglyph is present.

Study the surface of the disk and the tentacles. The former is frequently expanded and thrown into folds and lobes. The tentacles are elongated diverticula of the disk and are hollow. They are charged with nettle cells and are the principal organs of defense and offense. They are also useful in feeding; after the nettle cells have stung the small animals which constitute the food of the sea anemone, the tentacles place them in its mouth. The tentacles are not all the same size, those nearer the mouth being the larger and the older.

Note the character of the columnar body. It is pierced by small pores through which long, white, glandular threads, armed with nettle cells and called **acontia**, may be thrust when the animal is irritated.

Exercise 1. Draw the expanded animal, showing the column and the disk, with the mouth and the tentacles.

Internal Anatomy. Cut the animal into halves by a longitudinal incision passing at right angles to the mouth and from the disk to the foot. The mouth will be seen to open into a flattened tube with more or less corrugated walls, called the **gullet**. Note

the formation of the siphonoglyphs. The gullet leads into the **gastrovascular space**, which is the general internal cavity.

The most prominent structures in this cavity are the **mesenteries**, which are longitudinal partitions extending from the outer wall of the body inward toward its center. These mesenteries will be seen to occur in pairs; six of these pairs, called the **primary mesenteries**, join the body wall with the wall of the gullet. The pair at each angle of the gullet which inclose the siphonoglyphs between them are called the **directives**. Between the six pairs of primary mesenteries are **secondary**, **tertiary**, and **quarternary** pairs. The gastrovascular space is thus divided into a large number of partially separated longitudinal chambers.

Note carefully the structure of the free edges of the mesenteries below the gullet. The thickened, corrugated structure which forms the edge is the **mesenterial filament**; it contains digestive glands. From the base of the mesentery extend the acontia. The reproductive organs, the testes and ovaries, are also located in the mesenteries, lying alongside the mesenterial filaments. The sexes are separate and similar in appearance.

Note carefully the position of the longitudinal **muscle bands**, one of which is present on the surface of each mesentery. It is by means of these muscles that the body is contracted. A **circular muscle** in the disk closes the mouth by its contraction and aids in drawing in the tentacles.

Exercise 2. Draw a semidiagrammatic view of the cut surface of the animal, showing these features.

Make a cross section through the gullet and study the arrangement of the mesenteries, the relation of the primary mesenteries to the gullet, and the longitudinal muscles.

Exercise 3. Draw a diagram of the cross section, showing these features.

Make a cross section through the body beneath the gullet.

Exercise 4. Draw a diagram of the cross section, showing the arrangement of the mesenteries.

PHYLUM PORIFERA

CLASS: *Calcarea*

A SPONGE (*GRANTIA*)

Grantia is a noncolonial sponge which is common along the New England coast. It is a small, cylindrical animal, about half an inch in length, and occurs in small groups attached to rocks or other objects below low-water mark.

Place several specimens in a watch glass of water, and study their shape and external characters with the aid of a hand lens. Observe the cylindrical body and at one end of it a small opening surrounded by straight, needlelike spicules; the opposite end is the one by which the animal was attached. The opening is called the **osculum** or **excurrent opening**. Notice the smaller spicules and the openings of numerous minute pores which cover the sides of the body. Growing out from the base of the larger individuals may often be seen small ones, which in the course of time will become independent animals. Note the evident radial symmetry of the animal.

Exercise 1. Make a drawing of an animal on a scale of 5.

Split a dried sponge with a sharp knife into two equal halves and study it under a dissecting microscope. Observe the large **central cavity**. Large numbers of openings will be seen in its wall; they are the mouths of the **radial canals**, which are projections of the central cavity into the body wall. Examine carefully the cut edges of the body wall; observe the radial canals, which are cut longitudinally here. Notice also the shorter and less regular **incurrent canals**, which lie between the radial canals and open to the outside through external **incurrent pores**. There are thus two systems of canals in the body wall: (1) the **radial canals**, which are a part of the central cavity, and (2) the **incurrent canals**,

which open to the outside. These two systems of canals communicate with each other by means of minute openings, so that water which enters the incurrent canals from the outside through the external incurrent pores passes freely into the radial canals, and thence into the central cavity. From here it passes out through the osculum.

Exercise 2. Make a semidiagrammatic drawing of the inner surface of the body wall and the cut edge of the animal, showing the features described above.

Isolate the **spicules** of a sponge by boiling a portion of it in a caustic-potash solution. Mount some of them in water and examine them under a high power of the microscope. Find the three different kinds of spicules: the **long straight** ones which guard the osculum, the **short straight** ones which guard the external incurrent pores, and the **triradiate** ones which are within the body wall and give it rigidity and firmness; some of the latter project into the central cavity.

Exercise 3. Draw an outline of each kind of spicule on a large scale.

Make thin sections of a sponge by placing it between two pieces of elder pith or of cork, and shaving off the sections with a sharp razor or scalpel. Obtain in this way cross, longitudinal, and tangential sections. Mount them in water and study them under the microscope. Slides of stained sections can also be used.

Study a cross section in which the canals have been cut longitudinally. Observe the radial and the incurrent canals and their relations to one another. Note the arrangement of the spicules which guard the incurrent pores, also of those triradiate spicules which project into the central cavity.

Exercise 4. Make a drawing of several canals showing these features.

Study a tangential section in which the canals appear in cross section and study the arrangement of the triradiate spicules around them.

Exercise 5. Make a drawing illustrating it.

Specialized **reproductive organs** are not present in Grantia. The sexual elements will be found in the form of large, spherical bodies buried in the wall of the sponge. Fertilization takes place here, and when development begins the young embryos escape into the sea water through the canals. For a while the embryo is a free-swimming animal, but it finally fastens itself to a rock and develops into the adult sponge. Besides this sexual reproduction, the sponge also reproduces asexually by budding. Each distinct cluster of individuals probably represents the gemmated progeny of a single individual.

Special respiratory, excretory, digestive, circulatory, nervous, and locomotory organs are wanting in Grantia. **Respiration** and **excretion** are carried on through the entire surface of the body. The animal feeds on minute organisms and particles of organic matter suspended in the water which streams into the canal system through the incurrent pores. The radial canals are lined with peculiar entoderm cells called **collar cells**, each one of which possesses a **flagellum**. The action of the flagella produces the current of water through the canals, from which the collar cells obtain and ingest food particles. Circulation is from cell to cell.

PHYLUM PROTOZOA

CLASS: *Infusoria*

PARAMECIUM

Paramecium, often called the slipper animalcule, is one of the commonest of the larger infusorians. It is a minute, single-celled animal, being just on the limit of vision, and is often present in standing water which contains decaying vegetable matter. It may usually be obtained by permitting vegetable matter from a pond to stand in water for a week or two. In shape it is an elongated ellipsoid with a wide, slightly twisted, longitudinal groove, called the **oral groove**, on one side; the surface which contains the groove may be called the ventral surface, and the opposite surface, the dorsal. The animal is colorless and transparent, except when it contains within its body colored food particles.

Mount a drop of water containing Paramecia and some decaying matter together with a few strands of cotton on a slide, using a large, thick cover glass, and study the animals under a low power of the microscope. They will be seen swimming rapidly about, but will gradually collect around the decaying matter or be entangled in the cotton. If they do not become quiet in a few minutes, it is because there is too much water under the cover glass, and some of it should be withdrawn with a piece of blotting paper. Care should be taken that the water does not entirely evaporate.

Observe the unsymmetrical shape of the animal, and the difference between the anterior and the posterior ends. Notice the rolling over of the animal as it swims through the water; the peculiar spiral twist of the body is correlated with this motion, but does not necessarily cause it, since the animal may at times revolve in the direction opposite to that of the twist. It is in consequence of this peculiar revolving motion that the animal is able

to maintain a course through the water which is practically straight. The great majority of swiftly moving animals are bilaterally symmetrical, and move in straight lines because of that feature of their structure, but Paramecium, together with most free infusorians, has an unsymmetrical form and consequently would tend to move in circles without making progress, if it were not for the revolution of its body on its long axis.

Exercise 1. Draw several simple outlines of the body showing its shape as seen in different positions.

Exercise 2. Draw an outline of an ideal cross section through the middle of the body.

Study the structure of the body, using a high power of the microscope when necessary. Study the action of the hairlike, vibratile **cilia** which cover the outer surface of the animal and by means of which it moves. They are usually difficult to see in the live animal because of their very rapid motion, but by varying the light and the focus of the microscope they will be brought into view, and in the dead animal are plainly visible. Determine the direction in which the cilia move. Are they all of the same length? Note the delicate, transparent **cuticula** which covers the body; it appears as a highly refractive line.

The body has no internal cavity, and the protoplasm of which it is composed is in two distinct layers, the **ectosarc** and **entosarc.** The former is the thick, firm, transparent outer layer which, with the cuticula, gives permanent shape to the body; it often appears obliquely striated. The entosarc is the semifluid, granular mass which forms the remainder of the body. From near the anterior end the **oral groove** runs obliquely along the ventral side of the body to a point back of the middle, getting deeper as it goes. At its inner end the groove becomes a closed tube, which extends into the entosarc and ends with the **mouth.** Notice the **trichocysts,** slender, radially arranged bodies which fill the ectosarc. They are organs of defense, which remind one of the nematocysts of the Cœlenterata; when the animal is attacked by an enemy or irritated by a sharp reagent it discharges long, delicate bristles from the trichocysts, which project beyond the cilia and protect them.

They may also leave the body when the irritation is very severe and form a protective halo of bristles surrounding the animal.

Observe the granular nature of the entosarc, and the spherical **food vacuoles** within it. These are particles of food, usually composed of bacteria or minute particles of other vegetable substances surrounded by water, which circulate within the semifluid entosarc. Watch the entosarc closely, and observe the currents in it. Determine the direction of the currents and whether the direction is ever changed. The food vacuoles form at the inner end of the oral groove, where the particles of which they are composed have been swept by the cilia of the groove. Watch the formation of them; this may be done by putting grains of carmine or indigo into the water.

Observe the **pulsating vacuoles**. These are the **excretory organs** of the animal. They are globular drops of clear liquid, two in number, which appear near the aboral surface of the body, not far from either end, and break through the ectosarc into the surrounding water. They do not appear simultaneously, but alternate with each other. When a vacuole has disappeared, radiating canals of clear fluid gradually form about the spot where it was located, bringing the fluid which is to form the next vacuole at that end. Time the formation of the pulsating vacuoles; how many form in a minute?

Observe the **macronucleus**, a large, ovoid structure near the center of the body. At its side are either one or two minute **micronuclei**, according to the species, *Paramecium caudatum* having one and *Paramecium aurelia* two; they may be seen if the animal is killed by adding a 1 per cent solution of acetic acid to the water or a few drops of aceto-carmine solution.

Exercise 3. Make a large semidiagrammatic drawing of a Paramecium showing all these details, and label all.

Paramecium has no special vegetative organs except the pulsating vacuoles. Food vacuoles are taken into the entosarc through the mouth. Here they circulate for some time, while the water forming the vacuole is absorbed and the food particles that it contains are digested. The indigestible matters are

collected at a spot just back of the mouth and are there ejected from the body through a temporary opening in the ectosarc, which forms for that purpose; the water of the food vacuole is collected in the pulsating vacuoles and ejected. **Respiration** is carried on through the external surface of the body. The organs of **locomotion** are the cilia, which are distributed evenly over the surface of the body; they are hairlike projections of the ectosarc through pores in the cuticula. **Sensation** is exercised by the entire surface of the body. Place a minute crystal of salt on the slide and observe the reaction of the animals to it.

Reproduction is asexual, by division. A transverse constriction appears in the surface of the middle of the animal's body and deepens until it is divided in two. Each half becomes an independent animal and grows to full size. Look among a large number of animals for one which is dividing.

A process which is universal among infusorians is **conjugation**. Two individuals place the ventral surfaces of their anterior ends together. In this position their bodies fuse together and an interchange of micronuclear matter takes place between them. The two individuals then separate.

Conjugation was formerly supposed to be a process by which weak and infertile animals renewed their strength and vitality. It is now supposed to be rather a preparation for unfavorable life conditions. The change in the structure of the micronucleus leads to a change in the essential characters of the animals, and thus gives them additional powers of environmental adaptation and a better chance to survive unfavorable conditions.

Exercise 4. Look for dividing and also for conjugating individuals. Observe them carefully and draw them.

CLASS: *Infusoria*

VORTICELLA

This infusorian differs from Paramecium in being a sessile animal, and in that the cilia are not equally distributed over all parts of the body but are confined to certain parts of it. Vorticella and its allies are often called bell animalcules. The animal consists of a **bell-shaped body** at the end of a **long stalk** which is permanently attached to some object in the water. Around the upper and wider margin of the body is a row of large cilia. A deep **oral groove**, which is also bordered by cilia, extends from the margin toward the center of the animal and bears the **mouth** at its inner end.

A number of genera of bell animalcules are found in both fresh and salt water. Vorticella is noncolonial and possesses a contractile spiral stalk. Carchesium and Zoöthamnium are colonial and differ from each other in that in the former each individual animal contracts independently, whereas in the latter the entire colony always contracts as a unit; in both, the colonies are large and easily visible, appearing often like white mold on the object of attachment. Epistylis is colonial with a noncontractile stalk. These animals are all common.

Mount a drop of water on a slide, together with some vegetable or other substance to which Vorticella is attached, and study it under the microscope. (Any other bell animalcule will do equally well.) Observe the shape of the animal; tap on the slide with a pencil and cause it to contract; note the marginal cilia and the current they set up in the water; find the oral groove and note that the current in the water tends to sweep small objects into it.

Notice the partial radial symmetry of the animal; this body form is due to its sessile habit of life. Paramecium, which is a rapidly moving animal, is not radially symmetrical. Can you explain why a sessile organism tends to be radial?

Exercise 1. Draw a careful outline of the expanded animal on a large scale, and another of the contracted animal, and label the parts mentioned above.

Study the structure of the body. It consists of a single cell, as does Paramecium, and is composed of two protoplasmic layers: the **ectosarc**, which is the firm external layer, and the **entosarc**, the more fluid protoplasm of which the inner portion of the animal is composed. Covering its outer surface is the **cuticula**, which, with the ectosarc, gives the animal its permanent shape. The stalk is a continuation of the ectosarc and of the cuticula. Its inner portion alone, that is, the axis, is contractile; its cuticula simply accommodates itself by assuming a spiral shape. Note the longitudinal striations in the ectosarc at the base of the bell.

Observe the granular nature of the entosarc and the spherical **food vacuoles** within it; note the circulation of the latter in the granular protoplasm. Each food vacuole is composed of particles of organic matter in a minute globule of water, which collect in the oral groove and are then driven into the mouth. Watch the formation of them; this is done easily by placing grains of indigo or carmine in the water.

Vorticella has a single **pulsating vacuole**, which is in the upper part of the body. It is the organ of **excretion** of the animal and consists of a globule of clear liquid which collects near the surface of the body and is then discharged through the ectosarc into the water. As in Paramecium, the water which is ingested as a part of the food vacuoles is discharged through the pulsating vacuole together with renal products. Time the formation of the pulsating vacuoles; how many form a minute?

Observe the **macronucleus**; it is a narrow, elongated structure and is easily seen; near it is the small, spherical **micronucleus**.

Exercise 2. Make a large semidiagrammatic drawing of a Vorticella showing these details, and label all.

Vorticella has no special vegetative organs except the pulsating vacuole. The food particles which are ingested into the entosarc are there digested, and waste matters are egested through a temporary anus in the upper portion of the body. **Respiration** is carried on through the external surface of the body. Organs of **locomotion** are present in the cilia, by which the animal can swim

about if it is broken from its stalk. The axial fiber in the stalk is a delicate, striated muscle fiber. **Sensation** is exercised through the external surface.

Vorticella **reproduces** asexually, by a longitudinal division. The process begins at the upper end of the body and proceeds to the base, so that finally there are two individuals upon a single stalk. One of these now separates itself from the stalk, assumes a cylindrical form, and, having developed a band of temporary cilia near one end, swims away to find a place for itself. It soon attaches itself, loses the temporary cilia, and develops a stalk.

In the case of the colonial Vorticellidæ both of the individuals produced by the process of division remain on the stalk. In Zoöthamnium the colony is dimorphic; it contains nutritive individuals which are similar to Vorticella, and reproductive individuals which are large and globose and do not feed. The latter separate themselves from the parents and swim off and found new colonies. This dimorphism and division of labor remind one of the Hydromedusæ. In Vorticella, as in Paramecium, reproduction is largely a matter of sufficient nutrition, well-nourished animals reproducing faster than poorly nourished ones. Conjugation also occurs; it is brought on by the same conditions as in Paramecium and is highly important to the well-being of the race. The process is, however, somewhat different from conjugation in Paramecium. An individual divides into from two to eight parts. These free themselves from the stalk, acquire each a basal band of cilia, and swim about in the water until they come in contact with individuals of the ordinary kind, with which they fuse. A permanent conjugation is then effected instead of a temporary one as in Paramecium.

Conjugation, it will be noticed, while it is not a sexual process, is closely allied to such a process, and it is probably through it that sexuality arose in the organic world. In Paramecium and Vorticella we have two important steps in the development of sexuality. In the former animal the conjugating individuals are of the same size, or isogamous, and the fusion of the two individuals is

temporary, while in the latter they are of different sizes, or heterogamous, and the fusion is permanent. As a result of this differentiation in Vorticella one of the conjugating individuals is a large, passive form, and the other is a small, active, motile form, which finds and fuses with the passive form. A distinct foreshadowing of the two sexes which characterize the Metazoa is thus present.

Exercise 3. Look among a large number of Vorticellas for conjugating and for dividing individuals. Observe them carefully and draw outlines of those observed.

Class: *Mastigophora*

A FLAGELLATE (*EUGLENA VIRIDIS*)

This single-celled organism, which combines the characters of animals and plants, is often so plentiful in pools and ditches that it makes the water green. It is a minute, elongated protozoan, one end of which is pointed and the other blunt; in the latter end is the mouth, which leads into a depression called the **gullet**, from which springs a long, threadlike, vibratile **flagellum.** The body is covered by a very delicate **cuticula.** The animal is colored green by the presence of **chlorophyll** bodies in it.

Mount a drop of water containing Euglena on a slide and study it under the microscope. Observe its shape and color; observe also its swimming motions and the motions of the flagellum. The latter organ will be seen to be at the anterior end of the body; it is always in advance as the animal swims. The animal revolves on its long axis as it swims and describes a spiral path in its progress from one spot to another. In some flagellates the flagellum is at the posterior end. Whether the flagellum in any species of flagellate is at the anterior or the posterior end of the body depends upon the direction the vibratile motion of the flagellum takes. If the motion begins at the base of the flagellum and proceeds toward its tip, the animal's body will be driven ahead with the flagellum at the rear, whereas if the motion begins at the tip of the flagellum, the body will be drawn after it. Note the extreme plasticity of the body. It can assume a variety of shapes, and will often be seen swimming by the alternate contraction and expansion of the body, like a worm.

Exercise 1. Draw a number of simple outlines of the body showing its shape at different times.

Study the structure of the body. The protoplasm composing it is clear, its surface often showing delicate striations. Note the **cuticula.** In the middle of the body is a large, spherical **nucleus.** At the anterior end near the gullet is a clear space called the **reservoir**; find it. It receives the discharges of the **pulsating vacuoles.**

These are minute globules of clear liquid, which represent the excretory wastes of the animal; they collect and discharge into the reservoir periodically, which thus acts as a urinary bladder and in turn opens into the gullet. Near the reservoir is a red **pigment spot**, which is sensitive to light; it is the most primitive form of an **eye**.

Exercise 2. Draw Euglena on a large scale with the organs mentioned.

In its life processes Euglena partakes of the nature of both a plant and an animal. Through the agency of the chlorophyll, bodies of greater or less size called **pyrenoids** are manufactured; these produce carbohydrates, which constitute a large part of the food of the organism. The process goes on only during the daytime and is a characteristic plant process. But Euglena also ingests solid food after the manner of animals. Bacteria and other food particles are taken into the mouth at the anterior end and thence sink into the soft, protoplasmic body. **Excretion** is effected through the pulsating vacuoles; **respiration**, through the body surface.

From time to time Euglena encysts itself. It loses its flagellum, draws itself together into a spherical form, and secretes a **cyst** of cellulose. After a while it either throws off the cyst and assumes its former shape or reproduces by dividing into from two to eight small Euglenas. **Reproduction** thus takes place during the period of encystment; also at times free individuals reproduce by longitudinal division.

Exercise 3. Among a large number of individuals look for dividing and also for encysted ones. Make large drawings of several.

CLASS: *Sarcodina*. ORDER: *Rhizopoda*

AMŒBA

The amœba is a jellylike, single-celled animal which may be found in stagnant water attached to submerged objects, or in bottom sediment; it is also often found in moist, damp places which are not under water. There are many species, the largest being within the range of the unaided vision, the smallest species requiring high powers of the microscope to detect. Among the common species of amœba are *Amœba proteus*, a large, often active form with long pseudopodia, *Amœba verrucosa*, a large, sluggish form with very short pseudopodia, *Amœba limax*, a small form which flows along without definite pseudopodia, and *Amœba radiosa*, a small, star-shaped form with slender, radiating pseudopodia.

Mount on a slide a drop of water with sediment or scrapings from a submerged leaf or stick containing amœbas, and find one. Observe its shape and granular appearance. From time to time the shape of the body changes by the thrusting out of projections called **pseudopodia**. Observe the formation of pseudopodia.

Exercise 1. Draw several outlines of the animal showing its shape at different times.

Observe the structure of the body. The protoplasm forming it will be seen to be divisible into two layers, the **ectosarc** and the **entosarc**; the former is the clear, transparent layer which forms the periphery of the body; the latter is the granular, translucent mass which forms the remainder of it. The ectosarc is of firmer consistency than the entosarc, and its outer surface forms a delicate cuticula. When a pseudopodium begins to form, it consists at first of ectosarc alone, but entosarc finally enters it as it grows larger. The entire body will often flow into a single pseudopodium, in which case the animal flows in that direction. When this happens the ectosarc of the hinder portion of the body will be seen to wrinkle as the entosarc flows away from it.

Observe the granular nature of the entosarc and the flowing of

the granules as they move about with the motion of the protoplasm. Observe the **food vacuoles** in the entosarc; they are particles of food surrounded by water. Observe the **pulsating vacuole**, the organ of excretion, which is usually near the hinder end of the moving body. It will be seen to be a large globule of clear liquid which forms near the periphery and then discharges into the surrounding water. Time its pulsations; how many form a minute? Add a 1 per cent solution of acetic acid to the water, or a few drops of aceto-carmine solution, and find the **nucleus.**

Exercise 2. Make a large semidiagrammatic drawing of an amœba showing the features mentioned above, and label all.

Amœba has no special vegetative organs except the pulsating vacuole. Solid food consisting of plants and animals and particles of organic matter is ingested in the form of food vacuoles. These move about in the entosarc with the movements of the animal's body and the nutritive matters are digested and absorbed. Waste matters are then egested by being thrust out of a temporary opening in the ectosarc into the water. **Respiration** is carried on through the surface of the body. One reason for the active throwing out of pseudopodia is the necessity of increasing the relative area of the surface of the body for respiratory purposes.

Reproduction in Amœba is carried on by division. The nucleus first divides; the animal then elongates, and a transverse constriction appears in its middle, which is finally carried through the body. Two animals are thus formed, each of which contains half of the nucleus. As in other protozoans, reproduction in Amœba is largely dependent upon nutrition. If the nutritive conditions surrounding them are unfavorable, the animals gradually lose their vitality and reproductive powers and in the course of time will die. Conjugation also probably occurs, as in other Protozoa, although it has never been observed.

PHYLUM CHORDATA

SUBPHYLUM TUNICATA

CLASS: *Ascidiacea*

A SIMPLE ASCIDIAN (*MOLGULA*)

Ascidians are sessile, marine animals which live attached to rocks, seaweed, and other objects in the waters along our shores. Many ascidians are colonial animals; the young individuals, which arise by a process of budding, remaining attached to the parents. In a colony which is thus formed certain organs are often possessed in common, and a very intimate relation is established between its individual members. Molgula is noncolonial; it is usually found in clusters attached to rocks below low tide.

Molgula is a small, saccular animal, an inch or less in length. Its outer covering is a thick, tough **tunic**, or **test**, which is characterized by being partly composed of cellulose, a substance rarely met with in animals. The surface of the tunic is covered with numerous minute projections, among which sand and dirt lodge and cause the dirty appearance which characterizes it, except where it is in contact with that of other individuals.

The animal has two external body openings, the **incurrent opening**, or the mouth, and the **excurrent opening**, each of which is at the end of a projection of the body wall called a **siphon** and is fringed by short **tentacles**. The tentacles may, however, have been drawn into the openings and thus not be apparent. The incurrent siphon is at the anterior end of the body, the excurrent siphon represents the morphologically posterior end; the portion of the body lying immediately between the two is the dorsal side; the opposite side, which is very much longer and includes the surface of attachment, is the ventral side. A stream of water is drawn into the incurrent opening, bearing the minute organisms which constitute the animal's food and the air needed for respiration;

through the excurrent opening the water is ejected, charged with fecal matter and reproductive products.

Exercise 1. Make a sketch of the animal on a scale of 2 or 3; label the dorsal and ventral aspects and the siphons.

Beneath the tunic and in contact with it is the **mantle**, which is the remainder of the body wall, the tunic being a highly modified **cuticula** protecting its outer surface. Remove the entire tunic. This may be easily done by snipping it with scissors and then pulling it off with forceps; it is not tightly joined with the mantle. The mantle will be seen to be a transparent structure through which the internal organs appear. Observe the white **muscle bands** in the mantle, especially the **transverse** and **longitudinal muscles** in the siphons by means of which they are extended and contracted. Note also the short **tentacles** at the incurrent and excurrent openings. Count those at each opening.

The Digestive System. The most conspicuous internal organs are the cream-colored **genital glands** near the center of the body and the **alimentary canal**. The latter lies on the left side of the body, where it appears as an S-shaped structure which incloses the former. Place the body in water with the left side uppermost and the siphons away from you, and study the arrangement of the organs. The incurrent opening (at your left) will be seen to have more prominent tentacles than the excurrent opening. From the base of the incurrent siphon the large **pharynx**, the most voluminous organ of the body and the principal organ of respiration, will be seen extending to the lower side of the body. Note the six longitudinal ridges which appear as light-colored bands in the pharyngeal wall. Find and trace a white or cream-colored line extending in the midventral line from the base of the incurrent siphon to the opposite side of the body. This is the **endostyle**; it is a ciliated and glandular groove which lies between two folds in the midventral wall of the pharynx; it extends the length of that structure and ends posteriorly near the opening of the pharynx into the **œsophagus**. Find this point. The œsophagus is short and communicates with the **stomach**, and these two divisions form the lower and thicker limb of the S-shaped digestive tract.

The upper limb is formed by the **intestine**, which passes to the base of the excurrent siphon, where it ends with the **anus**. Find these organs.

The Reproductive System. Molgula is hermaphroditic. The sexual organs consist of a pair of large **hermaphroditic glands**, one of which is seen on each of the lateral sides of the body. A short duct runs from each gland to the base of the excurrent siphon. On the left side the duct will be seen alongside the posterior end of the intestine; find it.

The Circulatory System. On the right side of the body beneath the hermaphroditic gland will be seen the **heart** in its **pericardium**. It is a muscular sac from each end of which proceeds a large blood vessel. The vessel leaving the ventral end (at the observer's right) is called the **cardiobranchial vessel**; it passes along the mid-ventral side of the pharynx, beneath (external to) the endostyle, and gives off branches which run transversely along the pharyngeal wall. The vessel leaving the dorsal end of the heart is called the **cardiovisceral**; it breaks up into numerous branches, which ramify among the viscera and other parts of the body. From the viscera the blood is collected again in a vessel called the **visceral-branchial**, which passes along the mid-dorsal pharyngeal wall and gives off **transverse branches**.

The heart of tunicates is peculiar in that its pulsations change the direction of the flow of the blood alternately from the cardiobranchial to the cardiovisceral vessels, and back again. The contraction of the heart is of a peristaltic nature; it passes from one end to the other of it for a short time; then after a short pause the contraction is renewed, the peristaltic motion beginning at the opposite end and driving the blood in the opposite direction.

The Nervous System. About halfway between the two siphons, embedded in the mantle beneath the dorsal surface of the animal, lies a small **ganglion** from which **nerves** radiate. No organs of special sense are present, except the tentacles and minute eyespots at the incurrent and excurrent openings.

The Excretory System. Beneath the heart is an elongated, vesicular organ which is the single, unpaired **kidney**; it is ductless. Beneath the ganglion above mentioned is a small, glandular organ

called the **subneural gland**; it has a duct which communicates with the pharynx. The function of this gland is probably excretory; it is supposed to be homologous to the hypophysis of vertebrates.

Exercise 2. Make a drawing of the left side of the animal on a scale of from 4 to 6, showing all the internal organs which appear in that aspect. Label the dorsal and the ventral sides of the body and all the organs.

Exercise 3. Make a drawing of the right side of the animal showing all the organs which appear in that aspect.

Exercise 4. Make a drawing of the dorsal side showing the organs observed there.

The Peribranchial Chamber. Cut off the excurrent siphon at its base and with a needle or bristle probe the opening. The probe will pass into the large space between the mantle and the pharynx. This is the **peribranchial chamber**; it surrounds the pharynx on all sides, except in the midventral line, and communicates with the outside water through the excurrent siphon. It is not a part of the body cavity, but has been formed by an infolding of the outer surface of the body. Into it, near the base of the excurrent siphon, the digestive and genital tracts discharge their products for removal with the current of respiratory water which streams out of that siphon.

The Respiratory System. The principal respiratory organ is the pharynx, which communicates with the incurrent siphon by an opening fringed with a circular row of branched tentacles. Its walls are pierced by numerous slitlike, ciliated openings, called **stigmata**, through which the respiratory water streams from it into the peribranchial chamber. A current of water is thus maintained, which passes through the incurrent siphon into the pharynx, and thence through the stigmata into the peribranchial chamber, and out again at the excurrent siphon. The stigmata are vertical in position and are arranged in transverse rows, which extend across the pharyngeal wall, and are separated from one another by delicate **vertical bars**; the transverse rows have between them large **transverse bars**, and running longitudinally along the pharyngeal wall on each side are six large **longitudinal**

bars or **ridges**, which are easily seen and have already been mentioned. Through all these bars the blood circulates, being brought to them either by the cardiobranchial or the visceral blood vessels, and respiration is thus carried on.

Lay the animal with the left side uppermost. Slit open the incurrent siphon and the pharynx by inserting the point of fine scissors in the siphon and, after cutting its wall to its base, carrying the cut through the wall of the pharynx along the side of and parallel with the midventral line to the posterior end of that organ. Lay the pharynx open. The twelve large longitudinal bars will be seen projecting into the pharyngeal lumen. Trace them throughout their entire extent. Find with the aid of a dissecting microscope or a hand lens the rows of branched **tentacles** at the base of the incurrent siphon and count them.

In the midventral line note the **endostyle**; notice also that it is a groove. Trace the endostyle forward to the base of the siphon. At its anterior end the endostyle is continuous with a ciliated ridge which encircles the anterior end of the pharynx and is called the **peripharyngeal ridge**. This ridge is itself continuous on the dorsal side of the animal, that is, on the side opposite to the endostyle, with a ciliated longitudinal ridge called the **dorsal lamina**, which passes along the mid-dorsal line to the opening of the œsophagus at the posterior end of the pharynx. Trace the peripharyngeal ridge and the dorsal lamina.

These organs aid in the ingestion of the animal's food. The endostyle is a glandular and ciliated groove; the gland cells secrete a viscid substance which catches the food particles; the cilia create a current which drives them toward the anterior end. Here they meet a current created by the cilia of the peripharyngeal ridges which takes them around the pharyngeal wall to the dorsal lamina, along which they are driven posteriorly to the opening of the œsophagus.

Between the siphons note the **ganglion** and **subneural gland**.

Exercise 5. Make a semidiagrammatic drawing showing the structures which appear in connection with the pharyngeal wall.

Exercise 6. Make a large diagram of Molgula and show the relative positions of the different organs; label all.

SUBPHYLUM VERTEBRATA

CLASS: *Amphibia*. ORDER: *Salientia*

A FROG

The following descriptions will enable the student to identify the commonest species of frogs.[1]

Rana pipiens, the leopard frog. Green or brown, with large black blotches edged with white or yellow which lie in two irregular rows on the back; legs barred above; belly pearly or yellowish; length about $2\frac{3}{4}$ inches; lives in marshes and wet places or in the grass.

Rana palustris, the pickerel frog. Brown or greenish, with several rows of oblong square blotches on back and sides; length about 3 inches; common in cold springs or streams or in the grass.

Rana clamitans, the green, or spring, frog. Green or brown, with rounded spots all over the back; legs with several cross bands; beneath, pure white; length 3 inches; lives in ponds and streams.

Rana catesbeiana, the bullfrog. Green or brown, with faint dark spots above; head often bright green; beneath, with pale blotches; length 5 to 8 inches; lives in ponds and streams.

Rana sylvatica, the wood frog. Pale reddish brown; head small and pointed, with a dark band on each side between eye and arm; length $1\frac{1}{2}$ inches; lives in the woods and in the grass.

Three specimens will be needed for a complete dissection of the frog: one for the outer form and the greater part of the internal organs, including the heart and the great blood vessels entering and leaving it; one for the other blood vessels; and one for the skeleton. A partial dissection can be made with a single specimen. The animals should be preserved during the dissection in a 5 per cent solution of formalin or in cold storage.

Place the animal (alive if possible) under a glass or in a dissecting pan and observe its form and color. The body is short and compact, with a large head and mouth; the hinder end is characterized by the lack of a tail and by the great length of the hind legs. The color is such as to adapt it to the environ-

[1] These descriptions have been modified from H. S. Pratt's "Manual of the Vertebrates of the United States."

ment in which it lives, and may change from time to time, like that of a chameleon, although not to the same extent as in that animal.

The skin of the frog is without scales, claws, or other hardened integumentary structures, such as are possessed by other vertebrates. It is, however, provided with numerous integumentary glands which secrete a protective slime. The characteristic triradiate openings of these glands may be seen with the aid of a hand lens in skin which the frog has shed; pieces of skin will often be found in the water in which the animals have been kept.

The body of the frog may be divided into two regions, the **head** and the **trunk**. The neck region, which is wanting in fishes and is so characteristic of land vertebrates, is just beginning to make its appearance in amphibians. A distinct neck is not present; there is present, however, one cervical vertebra with which the skull articulates. The caudal region is also wanting in the adult. In the larval frog and toad a long tail is present, by means of which the animal swims; it is, however, gradually absorbed as the tadpole passes through its metamorphosis.

The Head. This body division is triangular in shape. The **mouth** is large and bordered by skinny **lips**, which close tightly together like the cover on a box and thus prevent air from escaping during the act of respiration. The eyes are large and protruding. Each is protected by two **eyelids**, the upper one of which is large and thick and with little power of movement; the lower one is semitransparent and movable.

In front of the eyes are the **nostrils**; each of these is provided with a valve which can be tightly closed. The nostrils communicate directly with the mouth. Probe them with a bristle. Back of each eye is a large, circular area, the **tympanic membrane**, or ear drum, which is thus on the outer surface of the body. Between the eyes is a small, dark spot which marks the **frontal organ**; it is a rudiment of a median eye. In the male frog, of certain species, a pair of large **vocal sacs** project from the hinder part of the head in the breeding season. Probe them from the mouth, if present, and determine their extent.

The Trunk. This body division is short and shows externally no marks of segmentation; it bears the appendages. In the middle of the back will be noticed a prominent hump, which indicates the position of the sacrum, where the hinder appendages articulate with the spinal column. At the posterior end of the trunk and slightly dorsal in position is the small opening of the cloaca, the **anus.**

The Appendages. Two pairs of **legs** are present; each leg is made up of three divisions, a **proximal**, a **middle**, and a **distal division.** In the foreleg these correspond to the upper arm, the forearm, and the wrist and hand respectively; in the hind leg, to the thigh, the shank, and the ankle and foot. The toes have no claws.

The forelegs are relatively short and weak and do not aid in locomotion. Four fingers are present, the thumb being rudimentary. In the male frog the first finger is thickened. The fingers are not joined by a web.

The hind legs are long and muscular and are the principal organs of locomotion both on land and in the water. While the animal is at rest the hind legs are folded together back of it in a position ready for springing. In this position the three divisions of the leg become apparent. In the distal division certain ankle bones are much elongated and make this the longest of the three divisions. The five toes are webbed, the medial (innermost) one being the big toe.

Exercise 1. Draw the animal as it sits or lies before you.

If the animal is still alive, it may be killed by placing it in a jar of water in which a small quantity of chloroform or ether has been put.

Exercise 2. Draw a dorsal view of the extended animal showing the features above mentioned; carefully label all.

Exercise 3. Draw a side view of the head.

The Mouth and Pharynx. Open the mouth as wide as possible; cut each angle of the jaw a little, if necessary, so that the mouth will remain open. The mouth and pharynx will be seen to be a

single space which extends back to the beginning of the œsophagus. With forceps pull the **tongue** forward; it is a slimy, band-like structure which is attached only at its forward end. The hinder end, which extends back into the pharynx, is bilobed. The lower jaw is without teeth. Just back of the tongue in the floor of the mouth may be felt the **hyoid cartilage**, which supports the tongue.

Back of the tongue is the **glottis**, a median, longitudinal slit which opens into the lungs. The glottis is in the middle of an elliptical elevation formed by the two **arytenoid cartilages**; it is usually closed, but may be opened with a needle. Place the end of a blowpipe in it and blow up the lungs.

The frog has two methods of respiration: (1) with the skin and the mucous membrane of the mouth and pharynx, and (2) with the lungs. Air is taken by regular inspirations through the nostrils into the mouth and pharynx, where it is acted upon by the highly vascular mucous membrane. It is also at irregular intervals taken by an act of swallowing through the glottis into the lungs. It is expelled from the lungs by the elasticity of their walls, which contain muscle fibers, and that of the muscular sides of the body. Immediately after the expiration air is again swallowed, so that the lungs are kept filled. The floor of the mouth will be observed in the live frog to oscillate rapidly and regularly. This act is not connected directly with the pulmonary but rather with the pharyngeal respiration.

The opening behind the glottis into the digestive tract is the gullet, or **œsophagus**. Probe it.

In the roof of the mouth note the upper jaw, in which is a row of teeth called the **maxillary teeth**. Just behind them in the forward part of the mouth, near the median line, are two small groups of teeth called the **vomerine teeth**. On each side of these is one of the inner openings of the nostrils. Probe them. Near the angle of the mouth on each side is the large opening into the tympanic cavity, the **Eustachian tube**. Probe one.

Exercise 4. Draw a sketch of the opened mouth and pharynx on a scale of about 2, and carefully label all the organs mentioned above.

The Internal Organs. Place the animal on its back in a dissecting pan containing water, with its head away from you, and pin it fast with a large pin through the tip of the jaw and one through each of the four legs. Raise the skin of the belly with forceps, and with scissors make an incision in it along the midventral line the entire length of the body.

Notice the looseness of the skin and the large space between it and the underlying muscles. This space is a lymph cavity. Note carefully the points where the skin is attached to the muscles. Note the large blood vessels on the inner surface of the skin; these are the cutaneous veins and arteries. The blood is brought to the skin to be aërated, an important part of the respiration of the animal being carried on through the skin.

Through the semitransparent muscles in the region of the forelegs may be seen and felt a number of platelike bones and cartilages. These form the pectoral (shoulder) girdle and the breastbone, which support the fore limbs. In the midventral line will be seen through the body wall a broad, dark line; it is the abdominal vein.

Observe the ventral body muscles; see page 187.

Lift up the ventral body wall with forceps, and with scissors make a longitudinal incision through it in the median line the length of the body, taking care not to cut the organs lying beneath. Pull the two flaps of the body wall gently apart and pin them. Examine the organs which lie in the abdominal cavity, but without disturbing any of them.

If the animal is a male, or a female which is not breeding, the most conspicuous organs will be the large, reddish **liver** and the **intestine**. If it be a mature female, the dark-colored, granular **ovaries** may occupy a large part of the space within the body cavity; in this case the ovaries should be removed so that the other organs can be studied.

Lying on the left side of the liver and wholly or partly concealed by it is the elongated **stomach**. In front of the liver in the median line is the conical **heart** within its membranous **pericardium**. Lying between the lobes of the liver may be seen the small, greenish, spherical **gall bladder**.

Make a transverse incision in each flap of the body wall. Turn the flaps to the side and pin them down, exposing fully the internal organs.

In addition to the organs already mentioned one or both **lungs** may be seen. They are usually shriveled, saclike organs which lie at the forward end of the abdominal cavity, concealed by the liver. If either is full of air, it should be punctured and made to collapse. At the hinder end of the abdominal cavity, between the base of the hind legs, the large **urinary bladder** will be seen; if it is not found readily, insert the blowpipe in the anus and inflate the bladder. Several elongated, yellowish bodies may be seen projecting from between the other organs; they are called the **fat bodies**.

The **abdominal cavity** is lined by a membrane called the **peritoneum**. Note that the organs in it are attached to the walls or to each other by thin membranes; these are the **mesenteries**; they are folds of the peritoneum.

Exercise 5. Draw an enlarged outline of the animal and in it the internal organs as they lie in the body cavity before they have been disturbed; label all carefully.

The Digestive System. This system consists of the mouth, pharynx, œsophagus, stomach, intestine, cloaca, liver, and pancreas.

The **mouth** and **pharynx** have already been studied. Without cutting anything, press the liver to the animal's right and fully expose the **stomach**. It will be seen to be a large, curved organ, the anterior, or **cardiac**, end being near the left lung at the side of the heart, and the posterior, or **pyloric**, end being near the median line of the body. The **œsophagus** is a short tube, not quite as wide as the stomach, which joins the cardiac end of that organ with the pharynx.

From the pyloric end of the stomach, which is marked by a constriction, the **intestine** proceeds, with many turns, to the hinder part of the body. It is composed of two divisions: the **small intestine**, and the **large intestine**, or **rectum**. The small intestine forms the greater part of it; its anterior portion, the **duodenum**, is bent forward so as to lie parallel with the stomach, and be-

tween them lies the whitish, irregularly shaped **pancreas**. The **rectum** is about half an inch long and forms the hinder part of the intestine; it is much wider than the small intestine and may often be recognized by its dark color. The rectum is continuous posteriorly with the **cloaca**, a short, wide vessel which lies between the base of the hind legs and finds an outlet through the **anus**.

Observe again the extensive **mesenteries** which bind the divisions of the digestive tract with the wall of the abdominal cavity.

At one side of the forward portion of the rectum will be seen a dark-red, spherical body, the **spleen**. Press the intestine and mesentery aside, — but without cutting them, — and observe the flattened, dark-colored **kidneys**, which lie close to the dorsal body wall. At their forward ends are the two yellow, spherical **testes**, if the animal is a male, or the irregular, saclike **ovaries**, if a female; in front of these organs are the yellow, finger-shaped **fat bodies**.

Observe closely the **liver** and **pancreas**. The former is composed of two main lobes, one of which is subdivided into two smaller lobes. Note carefully the connection between these two parts. Turn the whole liver forward, — but without cutting anything, — pin it there, and study its dorsal surface and the pancreas.

The **pancreas** is an irregular, whitish gland which lies in the bend made by the stomach and the duodenum. Near the hinder border of the liver note the spherical **gall bladder**. Find the **bile duct**, which joins the liver with the duodenum. It is a slender tube which issues from the gall bladder and, after receiving a number of branch ducts from the liver, joins the duodenum a short distance from the pylorus. It passes through the pancreas, from which it receives one or more small **pancreatic ducts**. Gently squeeze the gall bladder with forceps and force the dark-green bile into the duct; it will thus be easy to follow. If the bile will not flow, cut the gall bladder open and inject a carmine solution in it with a pipette.

Exercise 6. Make a semidiagrammatic drawing of the dorsal surface of the liver and pancreas, with an outline of the stomach and duodenum, showing the features just described; carefully label all the organs.

The study of the digestive system will be completed after the heart has been examined.

The Heart and its Vessels. The **heart** of the frog is composed of five divisions: a single ventricle, two auricles, the sinus venosus, and the truncus arteriosus. Observe the pericardium, which closely invests the heart.

The **ventricle** is the large, conical, posterior portion of the heart; by its contractions the blood is sent forward through the **truncus arteriosus**, which is the large, cylindrical vessel springing from its anterior end. The truncus divides into two large vessels which pass forward and leave the pericardial space. Each of these vessels then divides into three arteries, called the **aortic arches**, through which the blood is carried to all parts of the body. The anterior arch is called the **carotid arch**; it carries blood to the head. The middle arch is called the **systemic arch**. The right and left sides of this arch meet back of the heart and form the **dorsal aorta**, which lies just beneath the spinal column and distributes arterial blood to the trunk and extremities. The posterior arch is the **pulmocutaneous arch**; through it blood is carried to the lungs and the skin for aëration.

In front of the ventricle are the **right** and **left auricles**; they appear dark-colored in consequence of the thinness of their walls. On the dorsal side of the heart is a large, thin-walled, dark-colored sac, the **sinus venosus**. Blood is brought to the heart from the organs and tissues of the body by three large veins which enter the sinus venosus: these are the **right** and **left precaval veins**, which enter the forward end of the sinus, bringing blood from the forward part of the body; and the **postcaval vein**, which enters the hinder end of the sinus, bringing blood from the hinder part of the body. From the sinus the blood enters the right auricle. Blood is brought to the heart from the lungs by the **pulmonary vein**, which lies alongside the left precaval vein and enters the left auricle; this vein is formed by the union of a right and a left pulmonary vein, which bring blood from the two lungs.

Exercise 7. Make a drawing of the ventral aspect of the heart and the blood vessels, so far as these have been observed, on a scale of 2 or 3.

The Digestive System (*Continued*). Dissect this system in the following way. Lift up the liver with forceps, and with scissors free its anterior border from the tissues beneath it, being careful not to injure the lungs. Find the œsophagus, which joins the stomach with the pharynx. Note that the lungs also join the ventral wall of the pharynx. Take hold of the œsophagus with forceps, lift it up, and with scissors cut across the floor of the mouth in front of the lungs.

The forward end of the digestive tract, with the lungs, being thus cut loose from the body, can be bent backward. With scissors cut the stomach and liver loose from the tissues beneath them; cut the mesentery by which the intestine is joined with the dorsal body wall, being careful not to injure the flattened kidneys and testes or ovaries, and straighten the intestine out. The entire digestive tract, together with the lungs, will thus be removed from the body, except at its hinder end. Extend it in the water and pin it there, with the lungs attached to the pharynx, and the liver and pancreas attached to the duodenum by the bile duct.

Exercise 8. Make a drawing of the digestive system, with the lungs; label all the parts and organs belonging to it.

Slit open the stomach and the forward end of the intestine and note the ridges on their inner surface. Cut open a lung and note that it is a hollow sac with a network of ridges on the inner surface.

The Urinogenital System. The urinary and the genital organs are in close union with each other, notwithstanding their difference in function, and are conveniently studied together. The **urinary organs** consist of the paired kidneys, the paired ureters, the urinary bladder, and the cloaca.

The **kidneys** are two large, flattened bodies which lie close to the dorsal body wall in the posterior portion of the body cavity. The ureter is a straight white tube which runs from the outer posterior border of the kidney to the dorsal wall of the cloaca. The **urinary bladder** is a large, bilobed sac at the hinder end of the body cavity which springs from the ventral wall of the cloaca. Its opening into the cloaca can be applied

closely to the openings of the ureters, and it can thus receive the urine from them; in it urine is stored.

On the ventral surface of each kidney is an irregular, yellowish line which is called the **adrenal body**, an endocrine body.

The **genital organs** consist of the testes in the male and the ovaries in the female, and the ducts which conduct the genital products to the outside.

The Male. The **testes** are two yellow, ovoid bodies which lie against the ventral surface of the kidneys and are attached to the dorsal wall of the abdominal cavity by mesenteries. Joining each testis with the ventral surface of the kidney are about a dozen fine tubules, which are suspended in the mesentery. Through these the spermatozoa, which are formed in the testis, make their way into the kidney and thence into the ureter. This duct thus serves the double function of a ureter (an outlet for urine) and a sperm duct (an outlet for sperm) and is thus a urinogenital duct.

Many male frogs have rudimentary oviducts, which appear as a pair of slender white cords, each lying alongside the kidney.

The Female. The **ovaries** differ very much in size and appearance at different times of the year. In the springtime they are often so distended with the small, spherical ova that they may almost fill the abdominal cavity. If this is not their condition, they appear as a pair of folded, dark-colored bodies which lie on the ventral surface of the kidneys attached to the dorsal body wall by median mesenteries. The paired ducts through which the ova find their way to the cloaca are the **oviducts**. In adult females each of these ducts is a thick-walled, twisted tube which lies in the abdominal cavity against the dorsal body wall. Its anterior end opens into this cavity and is situated at the side of the heart and the posterior end opens into the cloaca. The posterior portion of the oviduct is expanded and forms a **uterus**, a reservoir for ova.

The ova escape from the ovaries by the rupture of their walls into the abdominal cavity; they then make their way to the mouths of the oviducts and through them into the cloaca. During this descent of the ova the albumen which surrounds them is secreted by the walls of the oviducts.

At the anterior end of the kidneys is a pair of prominent, yellow, branching **fat bodies**. They vary much in size at different times of the year, being largest before the breeding season and smallest after it.

While studying the urinogenital system, the organs of which it is composed need not be disturbed. With a strong scalpel cut through the bony pelvis exactly in the median line between the legs in order to expose the cloaca. The urinary bladder is a delicate structure which is attached to the body wall by mesenteries. It must be freed from these and great care taken not to cut either it or the cloaca.

Exercise 9. Make a semidiagrammatic drawing of the urinogenital system with the cloaca; label carefully all its parts.

The Nervous System. This system is made up of the following divisions: (1) the **central nervous system**, which is composed of the brain and the spinal cord; (2) the **peripheral nervous system**, which is composed of (*a*) the paired cranial and spinal nerves and (*b*) the sympathetic nervous system; and (3) the **special sense organs**.

The cranial nerves and the spinal nerves each number ten pairs; the former spring from the brain and the latter from the spinal cord and place these structures in communication with the various organs and tissues of the body. The sympathetic nervous system lies in the body cavity in connection with the cranial and spinal nerves and innervates certain important viscera.

Remove the urinogenital system from the body. Raise it carefully with forceps, and with fine scissors cut it loose from the dorsal body wall. Note the spinal column projecting into the body cavity, and lying ventral to it note a large blood vessel, the dorsal aorta; this must not be disturbed. The spinal column is made up of nine vertebræ and a long terminal bone called the **urostyle**. Identify them.

We shall study first the **spinal nerves** and the **sympathetic system**. Each spinal nerve is joined with the spinal cord by two roots, a dorsal and a ventral root, and passes out from the neural canal of the spinal column through a space between two

vertebræ. At the point where these two roots meet, the dorsal root bears a large ganglion called the **spinal ganglion**. This ganglion is embedded in a prominent white body present between the vertebræ, called the **calcareous body**.

The ten pairs of spinal nerves will be seen in the body cavity, where they appear as white strands which lie against the dorsal body wall on each side of the vertebral column. The most conspicuous ones are the seventh, eighth, and ninth nerves, which lie close together in the hinder part of the abdominal cavity. They emerge on each side from between the seventh and eighth vertebræ, the eighth and ninth, and the ninth and the urostyle respectively, and proceed straight back almost parallel with the spinal column. These nerves are joined with one another by short connecting branches and form a network, or plexus, called the **sciatic plexus**. From this plexus issue a number of nerves which proceed to the hinder quarters of the body and the hind legs. Of these the largest is the **sciatic nerve**, which goes to the hind leg.

Find the sciatic plexus. Follow the sciatic nerve into the leg as far as possible.

In the forward part of the abdominal cavity, on each side, is another much smaller nerve plexus called the **brachial plexus**, which is composed of the first three spinal nerves. Of these the second, which is the largest and most conspicuous, is a large white cord lying at right angles to the spinal column and emerging from between the second and third vertebræ; it is joined by a small branch from the first and one from the third spinal nerves, and passes to the foreleg.

The fourth, fifth, and sixth pairs of spinal nerves are delicate cords which emerge from between the fourth and fifth, fifth and sixth, and sixth and seventh vertebræ, and pass obliquely backward to the muscles of the back.

Find these nerves.

The **sympathetic system** consists of a pair of delicate **longitudinal nerves** which lie in the abdominal cavity on either side of the spinal column, close to the dorsal body wall. In each longitudinal nerve are ten enlargements, the **sympathetic ganglia**, from

each of which one or more short branches run to a spinal nerve. Find these nerves and their ganglia.

The first, second, and third of these ganglia lie close to the first, second, and third spinal nerves and are joined with them by short branches. The fourth to the ninth sympathetic ganglia, inclusive, are situated nearer the median plane than the first three; they, together with the longitudinal nerve, lie alongside the dorsal aorta, which will be noticed as a median, dark-colored tube. The fourth sympathetic ganglion is the smallest; the ninth is the largest and is joined with the ninth spinal nerve by several branches; the tenth is small and is often wanting.

Branches from the sympathetic nerves and their ganglia pass to the various viscera. The largest of these branches proceed from the fourth, fifth, and sixth ganglia, and after joining together form a large nerve, called the **splanchnic nerve**, which supplies the intestine and other viscera.

Study the sympathetic system; first find the longitudinal nerves and ganglia, and then observe their relations to the spinal nerves and ganglia.

Exercise 10. Make a semidiagrammatic drawing of the spinal nerves and the sympathetic system. Draw first an outline of the spinal column as it appears in the ventral aspect of the opened body cavity; number the vertebræ; draw the spinal nerves and then the sympathetic system.

The Brain and the Spinal Cord. In order to expose these organs remove the skin and muscles from the back of the head and trunk. Find the juncture of the skull with the backbone. By bending the head slightly down, a space about an eighth of an inch long, which is covered by a dark-colored membrane, may be made to appear between the skull and the backbone. Introduce one blade of the scissors into the skull through the opening, and make a cut along the side of the skull between the eyes. Make a similar cut along the other side, and with the forceps lift off the roof of the skull, thus exposing the brain. Similarly cut through the two sides of the neural canal, which contains the spinal cord, and expose it.

Carefully remove the dark membrane, the **pia mater**, which covers the brain, and observe its five regions: the cerebrum, the diencephalon, the optic lobes, the cerebellum, and the medulla oblongata.

The brain and spinal cord are hollow structures. A delicate canal, called the **central canal**, runs through the center of the cord; in the brain this canal widens out into a number of spaces which are called the **ventricles.**

The anterior and largest region of the brain is the **cerebrum.** It is made up of the two lateral **hemispheres.** The anterior ends of the hemispheres are fused and form the **olfactory lobe**, from the anterior end of which the two **olfactory nerves** pass to the nose.

Back of the cerebrum is the inconspicuous **diencephalon**, and behind that are the paired **optic lobes**, or midbrain. In the roof of the diencephalon will be seen, with the aid of the lens, several delicate structures. Near the center of it arises a threadlike projection called the **pineal body**, which extends forward over the diencephalon. In an early period of the larval life of the frog the pineal body extends through the skull to the skin on the top of the head between the eyes, where it joins the brown spot known as the frontal organ, which is the rudiment of the pineal eye; this connection is lost before the animal becomes adult.

Back of the optic lobes and separated from them by a deep groove is a narrow, transverse ridge, the **cerebellum**, and back of that is the **medulla oblongata**, which is continuous with the spinal cord. The dorsal wall of the medulla is a dark-colored, vascular membrane called the **posterior choroid plexus**, beneath which is the **fourth ventricle** of the brain. The triangular, depressed area which these structures form is called the **fossa rhomboidalis.**

The **spinal cord** is the portion of the central nervous system which lies in the neural canal of the spinal column. It is a thick white band, oval in cross section, from which the paired spinal nerves spring. At two points it is swollen: (1) where the spinal nerves which form the brachial plexus, and (2) where those forming the sciatic plexus, respectively, leave it. The hinder end of the cord tapers rapidly until it becomes a fine thread which extends into the urostyle.

Exercise 11. Draw the dorsal aspect of the brain and the spinal cord.

Study the **lateral surface** of the brain and the proximal portions of the **cranial nerves**. Ten pairs of these nerves are present in the frog; several pairs are so small, however, that they may not be seen.

The first cranial nerve is the **olfactory**, which extends forward from the olfactory lobe. Cut away the roof of the anterior portion of the skull and follow the two olfactory nerves forward. Each will be seen to branch a short distance in front of the olfactory lobe and be distributed to the walls of the nasal capsule.

Cut the olfactory nerves. Dissect away the left side of the skull and expose the left surface of the brain, preserving as far as possible the nerves which will be seen coming from it.

Lying close to the inner wall of the skull, at the hinder end of the orbit, is a yellowish body, often surrounded by a calcareous sac. This is the **Gasserian ganglion**, and must not be injured. Just behind the hemispheres the **optic nerve**, the second cranial nerve, issues from the ventral surface of the diencephalon and extends forward to the eye.

The third and fourth cranial nerves, the **oculomotor** and the **trochlear**, are very small and can hardly be found; they go to muscles of the eyeball. The oculomotor springs from the ventral surface of the midbrain, the trochlear from the dorsal surface between the optic lobes and the cerebellum.

The fifth, sixth, seventh, and eighth cranial nerves, which are the **trigeminal**, **abducens**, **facial**, and **auditory**, respectively, arise close together from the forward end of the medulla oblongata. The first three of these nerves, together with the anterior end of the sympathetic nerve, are united in the Gasserian ganglion. The trigeminal nerve is the largest of these three; it arises from the side of the brain just beneath the cerebellum and passes forward to the ganglion. The abducens is a very slender nerve which arises from the ventral surface of the medulla near the median line. The facial and auditory nerves arise behind the trigeminus. The auditory is the larger and passes directly to the auditory capsule; the facial is much smaller and passes alongside the trigeminus to the Gasserian ganglion.

The ninth and tenth cranial nerves, the **glossopharyngeal** and the **vagus**, respectively, arise from the side of the medulla, back of the auditory nerve, by four roots. These unite to form a single nerve, which emerges from the cranial cavity by a foramen at the side of the foramen magnum. Immediately back of this foramen it expands into the large **jugal ganglion**, from which the glossopharyngeal and the vagus proceed. The former passes forward to the tongue; the latter passes backward along the pharyngeal wall, giving off branches which supply the muscles of the shoulder, the larynx, heart, lungs, and stomach.

Exercise 12. Draw the lateral aspect of the brain on a scale of 3, and the cranial nerves so far as observed.

Study the **ventral surface** of the brain. Cut the cranial nerves and remove the brain from the skull. Put it into a dish of water and study its ventral surface. Identify the olfactory lobe, the hemispheres, and the structures belonging to the diencephalon. The optic nerves will be seen issuing from the **optic chiasma**, a structure formed by the crossing of the optic nerves on the ventral side of the brain. Behind the optic chiasma is the **infundibulum**, a large median projection which is divided into a right and a left lobe, and extending from the hinder end of which is a flattened body called the **pituitary body**. This body is lodged in a depression in the floor of the cranial cavity, and usually remains there after the brain is removed from the skull.

The ventral portion of the midbrain is formed by the **crura cerebri**, which lie beneath the optic lobe and are partly concealed by the infundibulum. Arising from the crura near the middle line may be seen the very delicate oculomotor nerves.

The medulla oblongata is but slightly wider than the spinal cord. A longitudinal groove is present in the midventral line of both.

Exercise 13. Draw the ventral aspect of the brain on a scale of 3.

The Vascular System. This system is made up of the following parts: (1) the **heart**, a muscular pump which is continually

driving the blood to all parts of the body; (2) the **arteries**, the vessels through which the blood is carried away from the heart; (3) the **veins**, the vessels through which the blood is returned to the heart; (4) the **capillaries**, the minute vessels which connect the veins and arteries.

Kill a frog and pin it down as directed on page 167. Make a midventral incision through the skin from the tip of the snout to the anus. Note the prominent cutaneous veins on the inner surface of the skin. Identify first the abdominal vein through the ventral wall of the abdomen. This vein lies in the body cavity against the ventral abdominal wall and will appear as a dark median line. Open the body cavity by a longitudinal incision in the midventral line from the anus to the tip of the lower jaw. Take great care not to cut the organs within.

Free the attachments of the liver to the body wall, spread the two flaps to the right and left, making a short transverse cut in each, and pin them fast, exposing fully the heart, liver, and other internal organs. In the female animal the ovaries should be removed if they obscure the other organs.

The heart and the blood vessels leaving and entering it have already been studied (page 172).

The Veins.[1] The veins may be divided into two groups, which are (1) the **systemic veins**, those which enter the sinus venosus, with their branches, bringing for the most part venous blood from the various organs and tissues; and (2) the **pulmonary veins**, which enter the left auricle, bringing arterial blood from the lungs.

We shall first study the systemic veins. These may be subdivided into two groups: (1) the **caval veins**, which bring blood directly to the heart; (2) the **portal veins**, which bring blood directly to the liver and kidneys, whence it goes to the heart.

[1] The veins and larger arteries are usually easily studied without being injected, the veins being colored by the blood in them. The animals should not be dissected fresh, but the blood should be permitted to harden in the veins first. If it is wished to inject them, this should be done through the abdominal vein in both directions for the portal systems, and through the postcaval for the remaining systemic veins. The arteries can be better studied if they are injected; this should be done through the ventricle and truncus arteriosus.

Three large caval veins are present, which enter the sinus venosus; two of these, the **right** and **left precavals**, bring blood from the anterior half of the body, including the forelegs; the other, the **postcaval**, brings blood from the posterior half of the body.

Turn the apex of the heart forward and observe the two large precaval veins which enter the sinus venosus at its forward end. Each precaval is formed by the union of three veins, which meet immediately in front of the heart. These are the **external jugular**, the most anterior of the three, which brings blood from the head; the **innominate vein**, the middle one, which brings blood from the brain, the shoulder, and the forearm; and the **subclavian vein**, the largest and hindermost, which brings blood from the arm and the skin.

Several small, glandular bodies are present near the external and internal jugular veins, of which the **parathyroid**, the **thyroid**, and the **thymus glands** are the most important. The first of these is a small, ovoid body which lies next to the inner ventral surface of the external jugular. The **thyroid gland** is a somewhat larger body near the parathyroid but dorsal to it. The **thymus** is a small, ovoid body just back of the hinder margin of the tympanic membrane near the innominate vein.

The **subclavian vein** is formed by the union of two veins, the **brachial vein**, which is one of the two veins returning blood from the foreleg, and the **great cutaneous vein**, which returns it from the skin. Follow the former vein and its branches. The latter vein occupies a peculiar position in that it is partly respiratory in function. It lies on the inner surface of the skin, receiving numerous branches, and may be traced forward into the head, where it receives branches from the mucous membrane of the mouth and the pharynx. It is, however, not wholly respiratory, as it also receives branches from muscles.

Exercise 14. Draw a diagrammatic sketch showing the precaval veins and their branches so far as observed.

The **postcaval** is a large median vein which enters the posterior end of the sinus venosus. It arises between the kidneys and runs

along the mid-dorsal wall of the abdominal cavity, just beneath the dorsal aorta, to the liver, through which it goes to the heart. Press the intestine to one side, but without cutting anything, and observe it and its branches.

The postcaval vein receives the following branches: the **renal veins**, five or six pairs in number, from the kidneys; the **spermatic veins** (in the male) or **ovarian veins** (in the female), from two to four pairs in number, which join the postcaval between the renal veins, bringing blood from the genital organs; the **adipose veins**, a pair of veins from the fat bodies; the **hepatic veins**, three in number, from the liver.

Exercise 15. Draw a diagrammatic sketch showing the postcaval vein and its branches so far as observed.

The Portal System of Veins. A portal vein is one which does not go directly to the heart but either to the liver or the kidneys, where it divides up into capillaries and distributes the venous blood throughout these organs. In the frog two portal systems are present: the **hepatic portal**, by which blood is taken to the liver, and the **renal portal**, by which it is taken to the kidneys.

The Hepatic Portal System. This system is made up of two large veins and their branches: the **abdominal vein**, which brings blood from the hind legs, and the **hepatic portal vein**, which brings it from the digestive tract and the spleen.

The **abdominal vein** is a median ventral vein which has already been seen; it will have been cut in opening the abdominal cavity. It is formed by the union of the **right** and **left pelvic veins**, which come from the hind legs. Trace the abdominal vein back and find them.

Turn the liver forward and expose its dorsal surface; fasten it with pins in this position. Trace the abdominal vein forward to the liver. Just to the left of the gall bladder it divides into three branches, two of which go to the right and left lobes of the liver, and the third joins the hepatic portal vein.

Study the **hepatic portal** and its branches. It is a short, wide vein which lies in the mesentery and enters the left lobe of the liver. Near the point where it enters the liver it is joined by the

branch of the abdominal vein just mentioned. The hepatic portal receives numerous **intestinal veins**, which lie in the mesentery and come to it from the small and large intestines. It also receives the **splenic vein** from the spleen, the two large **gastric veins** from the stomach, a **gastroduodenal vein** from the stomach and duodenum, and a number of small **pancreatic veins** from the pancreas. The anterior portion of its course is through the pancreas.

The Renal Portal System. This system is made up of veins from the hind legs, the dorsal body wall, the kidneys, and, in the female, the oviducts; it is joined with the abdominal vein by the pelvic veins, which have just been observed, and with the kidneys by the renal portal veins.

Two veins, the **femoral** and the **sciatic**, collect the blood of the hind leg on each side of the body. The femoral is the larger of these. It is a large vein which appears on the ventral surface of the leg, where it receives the large **pelvic vein.**

The sciatic vein lies on the back of the thigh. It passes forward and joins the femoral, and the vein so formed is the **renal portal**, which runs forward to the outer margin of the kidney at its hinder end. The vein then continues within the kidney close to its lateral margin and gives off numerous branches, which break up into capillaries in the kidney. At about the middle of the kidney a vein comes from the side and entering the kidney joins the renal portal. This is the **dorsolumbar vein**; it collects blood from the dorsal body wall. In the female a large number of veins from the oviduct also enter the lateral margin of the kidney and join the renal portal vein.

Trace the abdominal vein back and find the pelvic veins. Follow one of the pelvic veins back to the base of the leg, where it will be seen to join the prominent femoral. Trace this vein forward to its point of union with the sciatic vein; trace the renal portal vein to the kidney. Study the distribution of the femoral and sciatic veins in the leg. Observe the dorsolumbar vein entering the kidney in the middle of its lateral margin and study its distribution.

Exercise 16. Draw a semidiagrammatic sketch showing the hepatic and renal portal systems, together with an outline of the organs with which the veins enter into relations.

The Pulmonary Veins. The **common pulmonary** enters the left auricle. It is a very short vein and is formed by the union of the **right** and **left pulmonaries**, which come from the right and left lungs respectively. Each pulmonary vein lies along the medial side of the lung, the right pulmonary being somewhat longer than the left. Turn the apex of the heart forward and find these veins.

Exercise 17. Draw a diagram of the entire venous system.

The Arteries.[1] All the blood in the heart leaves it through the truncus arteriosus, the structure of which has already been observed. At its anterior end the truncus divides into a right and a left branch, each of which after passing through the pericardium again divides into three branches, the **carotid, systemic,** and **pulmocutaneous aortic arches.** The last named of these arches, which is the hindermost in position, branches off from the others a short distance in front of the pericardium; the other two usually remain together a short distance before separating.

The anterior aortic arch, the **carotid**, passes forward and dorsally a short distance and then divides into two vessels, the **internal** and the **external carotid arteries.** At this point the walls of the arteries are thickened and spongy, and the ovoid structure thus formed is called the **carotid gland**; it is not a gland, however, but probably acts as an accessory heart. The internal carotid, the larger of the two, goes dorsally and then forward and supplies the brain, the orbit, and the mucous membrane of the roof of the mouth. The external carotid passes directly forward and supplies the tongue and the muscles of the lower jaw.

The posterior aortic arch, the **pulmocutaneous**, takes blood to the lungs and skin to be oxygenated. On each side just back of the carotid gland it divides into two arteries, the **pulmonary** and the **great cutaneous.** The former passes back a short distance and then divides into three arteries which traverse the walls of the lung. The latter passes first forward and dorsally and then backward along the inner surface of the skin.

[1] The arterial system can be best studied after it has been injected; this should be done through the ventricle and the truncus arteriosus.

Exercise 18. Draw a semidiagrammatic sketch showing the distribution of these arteries so far as observed.

The middle arch, the **systemic**, supplies the greater part of the body with blood. The two sides of the arch pass dorsally, one on each side, around the œsophagus to the dorsal side of the body cavity, where they meet and form the **dorsal aorta**. This vessel runs just beneath the spinal column to the hinder part of the body cavity, where it divides into two arteries, the **iliacs**, which go to the hind legs.

Lift up the stomach and find the dorsal aorta; follow it forward to the meeting point of the two sides of the systemic arch, and then follow each side of the arch to the heart. Each side of the arch gives off the subclavian, occipitovertebral, œsophageal, and laryngeal arteries.

These arteries leave the arch near together. The **subclavian** is the largest and supplies the shoulder and foreleg. Follow it and its branches. The **œsophageal** and **occipitovertebral** are close together and go to the head, a branch of the latter — the **vertebral** — also passing back along the dorsal surface of the spinal column. The **laryngeal** arises in front of the others and goes to the head.

Just behind the point of union of the two sides of the systemic arch the dorsal aorta gives off the **cœliacomesenteric artery**. Observe that this large artery is a continuation of and receives most of the blood of the left systemic arch. The dorsal aorta thus receives most of its blood from the right arch.

The cœliacomesenteric artery supplies the stomach and intestine with blood. It soon divides into two branches, the **cœliac artery** and the **anterior mesenteric**, the former supplying the stomach, liver, and pancreas, the latter the small intestine, rectum, and spleen.

Posteriorly to the cœliacomesenteric artery four to six pairs of **urinogenital arteries** spring from the ventral surface of the dorsal aorta and go to the genital organs, kidneys, and fat bodies. Several pairs of small **lumbar arteries** also spring from the dorsal surface of the aorta and supply the dorsal body wall. Near the

hinder end of the dorsal aorta the small median **posterior mesenteric artery** leaves its ventral surface and runs to the rectum.

The **common iliac arteries**, which are formed by the division of the dorsal aorta, are large vessels which supply the hind legs. A short distance from its origin each gives off two small arteries: the **hypogastric**, which supplies the rectum, bladder, and ventral body wall; and the **femoral**, which goes to the thigh. After giving off these arteries the common iliac is known as the **sciatic artery**. Follow it and its branches into the leg.

Exercise 19. Draw a semidiagrammatic sketch showing these arteries so far as they have been observed.

Exercise 20. Draw a diagram of the entire arterial system.

The Muscular System. Most muscles in the land vertebrates are attached at both ends by means of tendons. One end is usually attached to a more or less fixed and the other to a more movable portion of the body, the former being called the **origin** of the muscle and the latter its **insertion**. The middle part of the muscle is called the **belly**; by its contraction the origin and insertion, and with them the skeletal pieces to which they are attached, are brought nearer together. Muscles are usually attached to the bones and cartilages; thick, fibrous membranes, called **aponeuroses**, which often cover muscles and other organs, may, however, serve the same purpose.

Kill a frog and completely remove the skin from the body, without injuring any of the muscles. Inasmuch as they are more or less transparent when fresh, it is well to let the animal lie in alcohol or formalin before the muscles are studied.

Fasten the frog on its back, with its head away from you, by means of a pin through the tip of the nose and one through each foot, and, without cutting anything, study the muscles of the ventral side of the body. On the head the broad, thin **submandibular muscle**, the fibers of which are transverse in direction, stretches across from one side of the lower jaw to the other. A median tendon separates the right half of it from the left half. A narrow strand of muscle, the **subhyoid**, lies at the hinder end of the submandibular, with fibers parallel to its fibers and at-

tached to it in the medial area. The lateral ends of the subhyoid find their origin in the hyoid cartilage.

At the forward end of the trunk is a group of four muscles which radiate from the base of the foreleg on each side toward the medial area of the body and may be called the **pectoral group.** Beneath the medial ends of these muscles between the forelegs will be seen the delicate **sternum**, or breastbone. The foremost of these muscles is the **coracoradial**. It is a wide muscle, the hinder half of which is concealed beneath the muscle next behind it. From its distal end a long tendon passes along the humerus to the forearm. The function of this muscle is to bend the forearm.

The other three muscles of this group are divisions of the **pectoral muscle.** The anterior two divisions, like the coracoradial, have their origin in the breastbone near the median line. The hindermost division, which is the largest, has its origin in the outer edge of the broad aponeurosis, which occupies the median area of the abdomen. All the divisions of the pectoral muscle have their insertion near the proximal end of the humerus in the upper arm and serve to bend the arm back.

Lying in front of the pectorals is the **deltoid muscle.** It consists of two principal portions, an anterior and a posterior portion, both of which arise near the median line along the forward border of the pectorals. They are inserted in the humerus and cover the insertions of the pectoral muscles. Determine the action of the deltoid muscle.

Back of the breastbone are the **abdominal muscles**, which form the ventral and lateral walls of the abdomen. Three pairs are present, the rectus abdominis, the external oblique, and the transversus.

Extending from the hinder end of the breastbone to the hinder end of the trunk is the aponeurosis just mentioned — a broad median band of connective tissue covering the midventral area of the abdomen. A similar aponeurosis is also present in the middorsal area.

The **rectus abdominis** muscles are a pair of longitudinal muscles which lie in the midventral area beneath the aponeurosis. A

narrow tendinous band called the **linea alba** lies in the median line and separates the right from the left rectus. There are also present in these muscles four or five transverse, tendinous bands which divide them into segments. This segmentation, which also appears in the rectus abdominis of many higher vertebrates, including man, is an inheritance from the metameric condition of the body muscles in the fishes and the salamanders.

The **external oblique muscle** forms the lateral wall of the abdomen on each side. It is a broad, thin muscle which extends from the mid-dorsal to the midventral aponeurosis, its fibers having an oblique direction. Immediately beneath this muscle is the **transversus**, the fibers of which have a transverse direction.

Exercise 21. Draw the ventral aspect of the body showing these muscles.

Study the superficial muscles of the ventral surface of the hind leg. The longest muscle of the thigh is the **sartorius**. It is a long band which extends along the middle of the thigh from the pelvis to the proximal end of the shank. Just in front of it is a broad muscle, the **vastus internus**, which forms the anterior border of the thigh. It forms also the anterior portion of a threefold muscle, the **triceps extensor femoris**, which is the principal extensor muscle of the thigh. The other two portions of this muscle are on the upper side of the leg; they are the **rectus anticus femoris** and the **vastus externus**, the latter being posterior to the former.

Posterior to the sartorius on the ventral surface are three muscles, the **adductor magnus**, the **rectus internus major**, and the **rectus internus minor**, the latter of which forms the hinder margin of the thigh. These are all, together with the sartorius, flexors of the leg.

On the lower leg, or shank, the large muscle which forms the calf is the **gastrocnemius**. At its lower end is the **tendon of Achilles**, which passes over the ankle and is continued in the **plantar aponeurosis**, a broad, tendinous band covering the sole of the foot. The front side of the shank is formed by the **tibialis anticus muscle.**

Exercise 22. Draw the ventral aspect of the hind leg.

Study the superficial muscles of the dorsal surface of the leg. The anterior half of the surface of the thigh is occupied by two muscles already noted, the **rectus anticus femoris** and the **vastus externus.** Posterior to the last-named muscle are the **biceps femoris**, the **semimembranosus**, and the **rectus internus minor**, the latter forming the hinder margin of the leg.

On the shank will be seen the large **gastrocnemius**, forming the calf of the leg; the **tibialis anticus**, forming its anterior border; and the **peroneus** between the two.

Exercise 23. Draw the dorsal aspect of the leg.

Without injuring the bones trace each of these muscles to its origin and insertion and determine which muscles are extensors and which are flexors.

The Skeletal System. This system is made up of two portions, the **exoskeleton** and the **endoskeleton.** The **exoskeleton** in vertebrates consists of the hardened bony or horny structures which develop in the skin and furnish an external protection to the animal. These structures are very poorly represented in the frog. The skin is naked, no bony or horny scales or other hardened integumental structures being present. The toes are also without claws. The only exoskeletal structures are the teeth and certain bones called membrane bones which form a part of the skull. These bones are, however, so intimately joined with the other bones and cartilages of the skull that they will be studied in connection with them.

The **endoskeleton** consists of the bony and cartilaginous framework of the body. It may be divided into the **axial skeleton**, which includes the skull and the spinal column, and the **appendicular skeleton**, which includes the framework of the two pairs of appendages, that is, the legs and the girdles which join them with the trunk. The breastbone may also be conveniently studied with the appendicular skeleton.

The Appendicular Skeleton. The anterior appendages consist of the **forelegs** and the **pectoral girdle**. This girdle is formed of a right and a left half which meet midventrally; here they enter

into a close union with the breastbone and form with it a bony and cartilaginous ring which almost completely encircles the forward part of the trunk.

Each half of the pectoral girdle supports one of the forelegs and is composed of two portions, a **dorsal** and a **ventral portion**. The former portion consists of two skeletal pieces of nearly equal size, the **suprascapula** and the **scapula**, which lie respectively on the dorsal and lateral sides of the body. The suprascapula — the dorsal half — is a broad, thin plate which extends upward over the spinal column. Its broad, free dorsal end is composed of cartilage; the remainder of it is bone. The scapula is an elongated plate of bone which extends from the suprascapula to the ventral side of the body.

The ventral portion of the pectoral girdle consists of two bony and three cartilaginous skeletal pieces. The two bones are the **coracoid** and the **clavicle**, the former being the larger and the more posterior in position, and extending from the scapula to the midventral line. Joining them and the scapula is an irregular cartilaginous mass in the hinder side of which is a depression, the **glenoid cavity**, in which the humerus articulates.

The **breastbone**, or **sternum**, lies in the medial area of the body, between the ventral ends of the two pectoral girdles, and is made up partly of bone and partly of cartilage.

Remove the pectoral girdle with the foreleg from the body. Inasmuch as it is not joined with the vertebral column it may be removed by freeing it from the muscles in which it is embedded. First locate accurately the delicate cartilaginous portions of the sternum; carefully locate also the delicate suprascapula on each side of the body. Then insert the blade of a small scalpel under the suprascapula on one side and free it from the muscles which lie over it. Pass the scalpel down to the scapula and then to the ventral portion of the pectoral girdle. Do the same on the opposite side of the body, and finally remove the entire girdle with the breastbone from the body. Disarticulate and remove the two forelegs and very carefully clean away the muscles.

The Foreleg. The skeleton of the foreleg is composed of three divisions, a proximal, a middle, and a distal division.

The **proximal division**, or upper arm, is composed of a single bone, the **humerus**. The head of it, which is cartilaginous, fits in the glenoid cavity and forms the shoulder joint. At the distal end is a large round projection, on each side of which is a ridge forming the articular surface for the bone of the next division.

The **middle division**, or forearm, is composed of a single bone, the **radioulna**. It is formed by the fusion of the radius and ulna, the two bones which are present in the forearm of most vertebrates. The larger part of this bone is the radius. Its proximal end is concave, the projecting process on it being the **olecranon**, or elbow. Its distal end has two articular surfaces.

The **distal division** is composed of the **carpus**, or **wrist**, and the **hand**. The carpal bones are six in number, arranged in two rows, a proximal and a distal row. The hand is made up of five **digits**, of which the first digit, or thumb, is very small and rudimentary. Each of the other four digits is composed of two parts: the **metacarpus**, the long proximal bone which articulates with the carpus; and the **phalanges**, two or three small bones which form the finger. The thumb contains a metacarpus alone.

Exercise 24. Draw an outline sketch of the pectoral girdle and breastbone, representing them in one plane, also the foreleg in outline, showing accurately all the bones and cartilages; label them all carefully.

The Posterior Appendages. These consist of the **hind legs**, and the **pelvic girdle** which joins them with the trunk.

The **pelvic girdle**, like the pectoral, is composed of a right and a left half which meet ventrally and form an arch. The dorsal ends of the arch articulate with the last vertebra of the spinal column, and at its ventral end, on each side, is the **acetabulum**, the articular surface of the hind leg. Extending backward from the last vertebra between the two sides of the pelvic girdle is the long bone called the **urostyle**, which forms the hinder part of the spinal column.

Each half of the pelvic girdle is composed of two portions, a **dorsal** and a **ventral portion**. The former consists of the long, slightly arched **ilium**, which forms the side of the arch and

articulates dorsally with the last vertebra. The ventral portion is disk-shaped and is composed of the ventral end of the ilium, a small, triangular bone called the **ischium**, and a small, triangular cartilage called the **pubis**; the pubis is anterior to the ischium in position.

Carefully strip the muscles from the pelvic girdle, disarticulate it from the vertebral column, and remove it and the hind legs from the body. Disarticulate the legs and thoroughly clean the pelvis.

The Hind Leg. The skeleton of this leg closely corresponds to that of the foreleg. It is made up of three divisions, a proximal, a middle, and a distal division.

The **proximal division**, or thigh, is composed of a single bone, the **femur**, the head of which fits into the acetabulum and forms the hip joint.

The **middle division**, or shank, is composed of a single bone, the **tibiofibula**. It is formed by the fusion of the tibia and the fibula, the two bones which are present in the shank of most vertebrates. The line of division between the two is very distinct.

The **distal division** is composed of the **tarsus**, or **ankle**, and the **foot**. The tarsal bones are five in number, arranged in two rows, a proximal and a distal row. The proximal row consists of two long bones, the **astragalus** and the **calcaneum**, which are united at both ends. The latter is on the inner side of the foot and corresponds to the heel bone of the higher vertebrates. The distal row is composed of three very small bones. The foot is made up of six digits, of which one is supernumerary and rudimentary; the others are the five digits which characterize the typical vertebrate foot. The supernumerary digit is on the inner side of the foot and consists of from one to three small bones. Each of the other five is composed of two parts: the **metatarsus**, a long bone which articulates with the tarsus; and the **phalanges**, two to four smaller bones which form the toe. The first digit on the inner side of the foot corresponds to the great toe.

Exercise 25. Draw the ventral aspect of the leg on a scale of 2, showing accurately the outlines of the bones and cartilages.

The Axial Skeleton. The Vertebral Column. Strip the muscles from the back. Disarticulate the head from the trunk.

The vertebral column is composed of nine **vertebræ** and a long, unsegmented bone called the **urostyle**, which forms its posterior portion. Four regions may be distinguished in it: a **cervical** region, consisting of the first vertebra; a **thoracolumbar** region, consisting of the succeeding seven vertebræ; a **sacral** region, consisting of the last vertebra; and the **urostyle**, which represents a caudal region.

A vertebra is made up of the following parts: the **centrum**, or **body**, which is the cylindrical ventral portion; the **neural arch**, on the dorsal side of the centrum, which with it forms the neural canal in which lies the spinal cord; and the **transverse processes**, a pair of long lateral projections. The neural arch is made up of a pair of **neural processes**, which form its sides, and the median **neural spine**, or **spinous process**, which forms its roof. On the anterior surface of the neural arch is a pair of articular projections called the **prezygapophyses**; on the posterior surface is a pair of corresponding **postzygapophyses**. It is by these projections that the vertebræ are locked together. Note the difference in size in the transverse processes of the various vertebræ.

The first, or cervical, vertebra is called the **atlas**. It differs from the other vertebræ principally in that it has no transverse processes (although occasionally they have been found), no prezygapophyses, and a thinner centrum. On its anterior surface is a pair of depressions into which fit the articular processes of the skull, the **condyles**. The last vertebra, or **sacrum**, has large, transverse processes with which the pelvic girdle articulates. It lacks postzygapophyses, and on the hinder surface of the centrum is a pair of prominences which articulate with the urostyle.

Exercise 26. Draw a view of the ventral aspect of the vertebral column.

Exercise 27. Remove the second vertebra, clean it thoroughly, and draw a view of its hinder end.

The Skull. The **skull** is composed of two regions, the **cranium** and the **visceral skeleton**. The former incloses and protects the

brain and the organs of special sense; the latter surrounds the mouth and pharynx, forming the framework of the jaws and tongue.

We shall begin with the study of the **lower jaw** and the **hyoid apparatus**, which supports the tongue. These structures belong to the visceral skeleton. The **hyoid** is a thin plate of cartilage, with a pair of long anterior and a pair of short posterior projections, which is embedded in the muscles of the lower jaw.

The **lower jaw**, or **mandible**, is a paired structure which is composed on each side of two bones called the **angular** and the **dentary**, the former of which is posterior to the latter, and a cartilage which articulates with the upper jaw.

The mandible is without teeth.

Without disarticulating the lower jaw, carefully dissect the hyoid apparatus from the floor of the mouth.

Exercise 28. Remove and clean the mandible and the hyoid apparatus and draw them on a large scale.

Thoroughly clean the remainder of the skull, but do not remove the tympanum.

Observe the great flatness and breadth of the skull. At its hinder end is the **foramen magnum**, the large opening through which the spinal cord enters the brain cavity. The cranium, which protects the brain and the special sense organs, is the narrow medial portion of the skull. On each side of it is the large oval opening in which the eye lies. The arch-shaped sides of the skull are formed by the upper jaw and other portions of the visceral skeleton.

The **cranial bones** fall into two distinct groups, those forming the brain case, or **cranium proper**, and those forming the **capsules** of the **special sense organs**. The primitive cartilaginous cranium, which is partly replaced or covered by these bones, persists throughout the life of the animal in great part, and appears on the surface in a number of places. In skulls which have been allowed to become dry this cartilage will have disappeared.

The **cranium proper** contains the following bones. At the posterior end of the skull and surrounding the foramen magnum

are the two **exoccipital bones.** Each exoccipital bears on its hinder surface a convex articular projection, the **occipital condyle,** by which the skull articulates with the atlas. At the side of each exoccipital will be seen a portion of the primitive cartilage.

The pair of long, flat bones which form the roof of the cranium and lie directly in front of the occipitals are the **frontoparietals.** Their anterior ends overlap a bony ring which encircles the forward end of the brain case; this is the **ethmoid.**

The ventral portion of the cranium is formed by two bones, the **ethmoid,** just mentioned, and the **parasphenoid.** The latter is a large T-shaped bone which covers the entire ventral portion of the cranium and overlaps the ethmoid; its lateral portions extend to the auditory capsules. At the sides of it, back of the ethmoid, will be seen the primitive cartilage. The large foramen of the optic nerve will be seen in the side of the cranium between the frontoparietal and the parasphenoid.

The Special-Sense Capsules. These are the auditory capsules at the hinder end of the skull and the nasal capsules at its forward end. The optic capsules do not ossify.

The **auditory capsules** are fused with the sides of the cranium proper and consist largely of cartilage. On the ventral side of the skull the lateral projections of the parasphenoid bone cover them. On the dorsal and anterior sides a bone called the **proötic** is present; it will be seen abutting the hinder part of the frontoparietal bone. Between the proötic and parasphenoid bones is the large foramen of the trigeminal nerve.

Ventral to the proötic on the side of the skull is a depression; at the bottom of this is a large hole called the **fenestra ovalis,** which looks inside the auditory capsule. The depression is the **tympanic cavity,** — the middle ear of higher vertebrates, — which in the fresh skull is covered laterally by the **tympanic membrane,** or **ear drum.** The fenestra ovalis is joined with the tympanic membrane by a small bony and cartilaginous rod called the **columella.** This small structure, like the ossicles of the mammalian ear, conveys the sound waves from the tympanic membrane to the inner ear. Skulls from which the tympanic membrane has been removed have often lost it.

The two **nasal capsules** lie side by side, fused with the anterior end of the cranium proper, and are also composed largely of cartilage. The ringlike ethmoid bone, which, as we have seen, forms the anterior end of the brain case, also forms the posterior end of the nasal capsules. Two pairs of membrane bones are present in these capsules, the dorsal **nasals** and the ventral **vomers**. The former are a pair of large bones which lie in a transverse position covering the cartilage just in front of the ethmoid; the latter are a pair of bones also in front of the ethmoid, on the ventral surface of the skull, each bone bearing a group of small teeth.

The **upper jaw** and the other remaining portions of the visceral skeleton still remain to be described. The upper jaw forms two distinct arches, an outer, or **maxillary, arch**, and an inner, or **palatopterygoid, arch**.

The three bones of the maxillary arch, on each side, are the **quadratojugal**, the small posterior bone; the **maxillary**, the long, thin bone which bears most of the teeth; and the **premaxillary**, the small anterior bone which forms the anterior end of the skull.

The two bones of the palatopterygoid arch, on each side, are the **pterygoid** and the **palatine**. The former is a large bone which lies at the hinder end of the skull, medial to the quadratojugal and the maxillary, and is best seen on the ventral surface. The palatine is a slender bone which lies on the ventral surface and extends from the maxillary at the forward end of the pterygoid transversely to the ethmoid.

The bones and cartilages by which the lower jaw is suspended from the cranium are called the **suspensorium**. In the frog it is formed on each side by a small cartilage, the **quadrate**, and a bone, the **squamosal**. The quadrate lies at the extreme lateroposterior end of the skull, in close connection with the quadratojugal bone and between the pterygoid and the squamosal; the lower jaw articulates with its outer surface. The squamosal is a T-shaped bone which lies on the dorsal surface of the skull in the region of the auditory capsule; it supports the tympanum.

Exercise 29. Draw a view of the dorsal aspect of the skull. Show accurately the outlines of the bones and cartilages.

Exercise 30. Draw a similar view of the ventral aspect.

CLASS: *Pisces*. ORDER: *Teleostei*

THE PERCH

The perch is one of the commonest fresh-water fishes. It is found almost everywhere in streams, ponds, and lakes, where it lives on small aquatic animals of every kind. Any other bony fish may be used in place of the perch; the differences in structure which exist will not confuse the dissection. Two or three specimens will be needed for each student, but a partial dissection can be performed with a single specimen. During the progress of the dissection they should be kept in a 5 per cent solution of formalin or in cold storage.

Observe the form and external markings of the animal. The body of the perch, like that of the majority of teleosts, is elongated and laterally compressed, with a wedge-shaped head and a terminal mouth; the hinder end is less compressed than the forward portion and terminates with the tail fin, which is the principal organ of locomotion. The other fins are all of good size and may be used both for purposes of locomotion and as a means of defense against attack, the sharp spines with which most of them are provided being formidable weapons.

The entire body, with the exception of a part of the head and the fins, is covered with **scales**, which overlap one another posteriorly. Examine them carefully on different parts of the body and note their arrangement and difference in size. If the fish is fresh, note the slimy, transparent epidermis which covers the scales; if it is not fresh, scrape off some of the dried epidermis. Note the **lateral line** which runs along each side of the body parallel with the back its entire length; it is an organ of special sense, being sensitive to vibrations in the water.

Observe the color bands and their arrangement. Are they bilaterally symmetrical? Note that the color consists of an aggregation of small dots, except where it forms solid masses. These dots are pigment cells; they are just beneath the epidermis in the outer layer of the dermis and may be scraped off with the epidermis. Note the structure of a single dot; it will be seen to

consist of a black central kernel — the body of the cell — surrounded by a halo of fine dots, which constitute its outlying projections. Many fishes have the power of changing their color in a remarkable degree, although it is probably a reflex action in them and not under the control of the will. It is accomplished by the often very rapid variation in the extent of these pigment cells, which in such cases are amœboid.

The body may be divided into three regions, the **head**, **trunk**, and **tail**, the boundary between the latter two regions being the anus. There is no neck.

Vertebrates which live in the water differ much from those living on the land in the arrangement of the body regions. Water animals must force their way through a dense medium, and hence the forward portion of the body is rigid and usually more or less wedge-shaped. A neck region is thus absent, since a neck region is essentially flexible. Even in those mammals which have adapted themselves to a wholly aquatic life, as the cetaceans, the neck region is so much reduced that the head and trunk are in direct contact with each other. In every animal which moves rapidly, however, at least one flexible body region must be present, where the body can turn when the direction of movement is to be changed. In the fish this is accomplished in the caudal region; in most mammals it is in the lumbar region.

The Head. The head of fishes differs from that of land vertebrates in that it contains the organs of respiration and the heart. The head of the perch is flattened ventrally and dorsally, with the large **mouth** at its anterior and the **gills** at its posterior end. The opening of the mouth is bounded ventrally by the paired **mandibles**, and dorsally by the paired **premaxillæ**, above which on each side is the flattened **maxilla**. The large **eyes** are without lids. A transparent membrane called the **conjunctiva** passes over the front of the eye and is continuous with the epidermal layer of the skin; a deep fold of the skin is also present around the eye, joining it with the skin of the head, and yet permitting it considerable freedom of motion in its socket.

In front of the eyes are two pairs of **nostrils**; there is, however, but a single pair of nasal capsules, each capsule having two ex-

ternal openings. Note the difference in shape of these two nostrils and the valve which overhangs the anterior one. The nasal capsules do not open posteriorly into the mouth, but are wholly sensory in function.

At the posterior end of the head is the large **operculum**, or gill cover, and at its hinder margin, the **gill openings**. Note the sharp protective spine which projects back from each gill cover. Along the hinder and lower border of the gill cover is the **branchiostegal membrane**, supported by seven parallel, bony rays, the **branchiostegal rays**, which forms a valve guarding the gill opening. Underneath the gill cover on each side will be seen the four **gill arches**, which bear the red **gills**, and the clefts between the arches. Note the rudimentary gill, which appears as a red patch on the inner surface of the gill cover in front of the first gill arch.

Cut off the left gill cover and probe between the gill clefts into the pharynx. Observe carefully the form and position of the gill arches and the double row of **gill filaments** on each; also the **gill rakers**, the row of spiny projections on the side of each arch, which prevent food from passing through the clefts.

The Trunk and Caudal Region. These two regions pass gradually into each other; they bear the **appendages**. At the posterior end of the trunk are the **anus** and the **genital** and **urinary pores**. The anus is the largest and most anterior of these three openings; the other two are minute and are situated behind it on a small papilla. Behind this is often a transverse depression.

The Appendages. Two kinds of appendages are present, the **paired fins** and the **median fins**. The latter are alone present in the lowest fishes; they are simply dorsal and ventral flattened expansions of the body which are stiffened by bony rays. In the perch two **dorsal fins** and one **ventral**, or **anal**, **fin** are present, and one **caudal fin**. Note carefully which of these fins have sharp, spiny rays, and in which the ends of the rays are divided and flexible. Observe that the two dorsal fins are nearly continuous with each other.

The paired fins are also expansions of the body wall, stiffened by bony rays; they are homologous to the appendages of the higher vertebrates. Two pairs are present: an anterior pair,

the **pectoral fins**; and a posterior pair, the **ventral**, or **pelvic, fins**. The former are nearly vertical in position and are situated on the side of the trunk just behind the gill cover. They are supported by a bony arch within the body wall just back of the gills, which is called the **pectoral girdle**. The pelvic fins are a short distance behind them and are nearly horizontal in position. Note that in all the fins the rays with split tips are segmented.

Exercise 1. Draw an outline of the right side of the animal; do not draw the scales. Label the organs carefully.

Exercise 2. Draw the ventral view.

The Internal Organs. It will be well first to cut off the sharp tips of the dorsal fins to keep them from hurting the hands. The internal organs will be exposed by removing the left side of the body wall. After placing a probe in the anus to mark it, make a straight incision through the body wall from just in front of the anus to the mouth, cutting through the midventral point of the lower jaw. Care must be taken not to cut the organs which lie in the body cavity. Now lay the fish in a dissecting pan with the head to your left and its ventral side toward you, lift up the cut edge of the body wall with forceps, and with scissors cut away the left body wall and remove it, taking great care not to injure any of the internal organs. The ribs of the left side and the muscles attached to them, the left pectoral fin, and the left pelvic fin will thus have been removed.

It is best in doing this to work from the midventral incision upward, as in this way the internal organs are brought gradually into view as the work proceeds. The liver, intestine, and reproductive organs, the latter sometimes very large, will first be seen; then, dorsal to them, the air bladder. This organ adheres closely to the body wall and special care must be taken not to injure it; its ventral wall forms a wall across the body cavity which is tough and strong, its lateral walls becoming thinner dorsally.

Place the animal in a pan of water and examine the organs, without, however, disturbing them. Note the glistening **peritoneum**, the membrane which lines the abdominal cavity; it passes along the ventral side of the air bladder. The **mesenteries**,

the membranes which support the intestine and the other organs in the abdominal cavity, are folds of the peritoneum.

The **body cavity** is made up of two divisions, the larger and posterior of which is the **abdominal cavity**, the anterior and very much smaller one being the **pericardial cavity**. The former is lined by the **peritoneum** and contains most of the viscera; the latter is lined by the **pericardium** and contains the heart. These two cavities are separated from each other by the **false diaphragm**, which is composed of the posterior wall of the pericardium and the anterior wall of the peritoneum; it is not homologous to the diaphragm of mammals.

In the abdominal cavity the largest organ is the **air bladder**, which extends the entire length of the cavity and occupies the dorsal half of its space. On the inner surface of its ventral wall a pair of red patches composed of a network of capillaries will be noticed. The air bladder is a hydrostatical apparatus by means of which the fish can maintain its position in the water at different depths without conscious effort.

At the anterior end of the abdominal cavity and just back of the false diaphragm is the large red **liver**; at the posterior end, running back to the anus, is the **intestine**, which is usually inclosed in fat. The anterior portion of the intestine forms a coil lying a little to the right of the median plane, within which, often embedded in fat, lies the **spleen**. On the animal's left, more or less covered by the hinder border of the liver, is the **stomach**, a large, cylindrical body; alongside of it are several elongated **pyloric appendages**.

The **gonads**, or **genital glands**, consist of the paired testes in the male and the single ovary in the female, and lie dorsal to the intestine, extending from the hinder end of the cavity forward. If the female is studied during the breeding season, the ovary may occupy a large portion of the abdominal cavity and conceal the other organs.

In the pericardial cavity, dorsal to the thick muscles between the gills, will be seen the **heart**. It consists of the median **ventricle**, a large, muscular organ, at the sides of which appears the deep-red **auricle**; at the back of (dorsal to) this organ is the **sinus**

venosus, a large, deep-red sac which communicates with the auricle. In front of the ventricle is the large **bulbus arteriosus**, which is the beginning of the aorta.

Exercise 3. Make a semidiagrammatic sketch of the left side of the fish, showing the opened body cavity and its organs as they appear before they have been disturbed; label them all carefully.

The Digestive System. This consists of the mouth, pharynx, œsophagus, stomach with the pyloric appendages, intestine, and liver.

The Mouth and Pharynx. Cut away the left half of the lower jaw and the gill arches; the mouth and pharynx are thus fully exposed. They will be seen to form a single large space extending from the opening of the mouth to the œsophagus, the pharynx being the portion of the space which contains the gills.

The teeth are very small and are present not only in the upper and lower jaws but also on the roof of the mouth and the roof and floor of the pharynx. Examine them carefully with the aid of a hand lens. There are three groups of teeth on the roof of the mouth, a small median patch of **vomerine teeth**, and a pair of lateral patches of **maxillary teeth**. Note carefully the position of the teeth on the gill arches.

Just within the margin of each jaw is a transverse membrane; probe behind them. These two membranes are the **oral valves**, which prevent the water from flowing out again through the mouth during respiration. Breathing consists of two actions, the inspiration and the expiration. At the inspiration the oral valves open and the branchiostegal membranes, which form valves at the opening of the gill cover on each side, close; at the expiration the oral valves close and the branchiostegal valves open, allowing the respiratory water to pass out through the gill clefts.

Observe carefully the form and arrangement of the **gill arches**. Note the **gill rakers**, the short, spiny projections on the gill arches which prevent solid substances from passing out through the gill clefts. Cut out a gill arch and examine the **gills** on it. Observe that a double row of **gill filaments** is present. Study

carefully the arrangement of these filaments with reference to the gill arches and with reference to each other. In fishes the gills are outgrowths of the wall of the pharynx. In the ventral wall of the mouth is the **tongue**; note its relation to the gill arches.

Exercise 4. Draw a sketch of the mouth and pharynx showing both dorsal and ventral surfaces with the features above described.

Study the remainder of the digestive tract. Observe the short, wide **œsophagus**, which joins the pharynx with the stomach. Turn the left lobe of the liver to one side and observe the anterior, or **cardiac**, end of the stomach. Note the shape of **the liver** and the mesentery which attaches it to the anterior abdominal wall; cut this mesentery. Note the mesentery which joins the stomach with the ventral wall of the air bladder, and cut it. Note that a part of the intestine lies free and is not attached to the body wall by a mesentery. Cut the œsophagus and remove the entire digestive tract from the body, retaining, however, its posterior attachment at the anus.

Study the various parts of the digestive tract. The stomach has three distinct regions: an **anterior region**, which extends straight back from its cardiac portion and ends posteriorly in a blind sac; a **posterior region**, which leaves the anterior region at right angles near its middle and extends to the beginning of the intestine; and the **pyloric appendages**, three long, cylindrical blind sacs. Just back of these appendages is a slight constriction which marks the **pyloric**, or hinder, end of the stomach.

The **intestine** begins at the pylorus and extends to the anus. It is composed of three divisions: the **duodenum**, which includes the anterior loop of the intestine, between the limbs of which the spleen lies; the **small intestine**; and the **rectum**. The boundary between the last two divisions is the circular ridge about an inch in front of the anus. The **liver** is a large gland which communicates with the intestine by means of the **bile duct**. This duct emerges from the **gall bladder**, which lies against the posterior surface of the liver, receives a number of branch ducts from the liver, and joins the intestine near the base of the pyloric appendages. A pancreas has not been found in the perch.

Exercise 5. Draw a semidiagrammatic sketch of the digestive tract and label carefully all its parts.

The Urinogenital System: the Male Genital Organs. The **testes** are a pair of white, elongated bodies which lie in the abdominal cavity just ventral to the air bladder, to which they are joined by a mesentery. They taper toward the hinder end and finally fuse together, the median portion thus formed passing directly to the genital pore just behind the anus. The actual size of the testes depends upon the sexual condition of the animal; during the breeding season they are large and may extend into the anterior portion of the abdominal cavity.

The Female Genital Organs. The **ovary** is a median body which lies in the abdominal cavity between the intestine and the air bladder, and is joined to the latter by a mesentery. It is an elongated sac filled with small ova and varies in size with the sexual condition of the animal; no oviduct is present, the hinder part of the ovary becoming gradually smaller and finally communicating with the outside through the genital pore just back of the anus.

Exercise 6. Make a sketch of the genital organs.

The Urinary Organs. Remove the testes or the ovary. Dissect the air bladder away from the body wall and remove it. Note the thinness of its dorsal wall, where it lies just beneath the **kidneys**. These organs are a pair of slender, deep-red bands which lie close against the dorsal body wall, one on each side of the vertebral column. Their anterior ends unite just dorsal to the œsophagus and form a large, dark-colored median mass called the **head kidney**, which extends across the body cavity. Dissect away the remains of the œsophagus and note the exact shape and extent of the head kidney. The **ureters** are a pair of tubes which run along the entire length of the medial borders of the kidneys, joining at their hinder ends. The single vessel thus formed then passes to the minute **urinary pore** just back of the genital pore; a small **urinary bladder** projects from the median portion of the ureters.

Exercise 7. Draw a sketch of the urinary system within an outline of the body and the body cavity.

The **nervous system** consists of (1) the **central nervous system**, which includes the brain and the spinal cord; (2) the **peripheral nervous system**, which includes the paired cranial and spinal nerves and the sympathetic nervous system; and (3) the **special sense organs.**

We shall study first the **special sense organs** and then the brain. The peripheral nerves will not be studied in this dissection. The special senses are located in the integumentary sense organs, the nasal capsules, the eyes, and the ears.

The **integumentary sense organs** consist of (1) minute, scattered **sense buds** which occur principally on the head but also on the body, and (2) of the **lateral line.** This line is a straight canal in the integument which extends along the side of the body from the head to the caudal fin, with branches also upon the head, in which are groups of sensory cells.

The **nasal capsules** are a pair of sacs situated in front of the eyes and communicating with the outside by two nostrils on each side; no communication with the mouth is present. Cut off the outer wall of one of the capsules and observe the delicate folds of the sensory epithelium radiating from a central point.

Exercise 8. Make a drawing of the capsule on a large scale.

The Eyes. Observe the central **pupil**, through which light is admitted to the interior of the eye; the **iris**, which surrounds the pupil; and the transparent **cornea**, which lies in front of both and forms the outer coating of the eye. Observe carefully the circular fold of the skin which surrounds the front of the eyeball.

With strong scissors cut away the circular ridge of the skull which surrounds the eye, and remove the muscles of the head just beneath and back of it. Remove also the slimy fold of the skin just mentioned, which surrounds the front of the eye. Note that a transparent layer of the skin passes over the cornea and may be peeled off; this is the **conjunctiva.**

Observe the position of the eye in the orbit; it is held in place

by the optic nerve, which joins it at its inner end, and by six small muscles. These muscles have their origin in the wall of the orbit, and their insertion in the outer coating of the eyeball, the movements of which they control.

Study these **muscles**. Press the eyeball downward and note on its medial side the insertions of two muscles; the anterior one is the **superior oblique**, which goes from the eyeball to the inner, anterior wall of the orbit; the posterior one is the **superior rectus**, which goes from the eyeball to the inner posterior wall of the orbit. Push the eyeball backward and note the **inferior oblique muscle**, which has its insertion on its anteroventral surface and passes parallel with the superior oblique to the inner anterior wall of the orbit. On the posterior side of the eyeball is the insertion of the **external rectus muscle**, which runs to the inner posterior wall of the orbit. Cut the superior oblique muscle at its insertion in the eyeball; beneath it will be seen the insertion of the **internal rectus**, which runs back to the inner posterior wall of the orbit. Cut all these muscles at their insertion in the eyeball and pull it gently outward and forward; the **inferior rectus** will be seen, whose insertion is on the inner side of the eyeball and which runs to the inner posterior wall of the orbit. Cut this muscle and the optic nerve and remove the eyeball from the orbit. Note the origins of the four rectus muscles in the posterior wall of the orbit, and of the two oblique muscles in the forward wall of the orbit.

Exercise 9. Draw a sketch of the orbit showing its muscles and the optic nerve.

Study the eyeball. Its wall is composed of three coats, the **sclera**, the **choroid**, and the **retina**. The tough outer covering is the **sclerotic coat**, or the **sclera**, of which the cornea is the portion in front. Cut the eyeball in two lateral halves; remove the other eye and cut it in an anterior and a posterior half; study the interior of both under water. Just back of the pupil is the spherical **crystalline lens**, held in place by the iris; do not remove it. This is the shape of the lens in all vertebrates which live under water. In a dense medium like water vision is necessarily limited in

range, and fishes can see only those objects which are close to them. An eye with a spherical lens is shortsighted.

The inner coating of the eye is the **retina**. Between it and the sclerotic coat is the **choroid coat**, which is black on its inner surface and lies just beneath the retina, and silvery on its outer surface, just within the sclera. The portion of the choroid which extends over the front of the eye is the **iris**, the central opening of which is the pupil; delicate muscles in the iris control the size of the pupil.

Note the **blind spot**, the point where the optic nerve enters the eye. From near this spot a slender projection of the choroid, called the **falciform process**, extends through the retina to the side of the lens, to which it is attached.

The two large chambers of the eye are the one between the iris and the cornea, which is filled with the watery **aqueous humor**, and that between the retina and the lens, which is filled with the jeliylike **vitreous humor**.

Exercise 10. Draw a diagram representing the structure of the eye.

The Ear. The auditory organ consists of the membranous labyrinth alone, which is embedded in the cranium back of the eye; no external opening exists. To dissect it out is a difficult task, which will not be done in this dissection.

The Brain. If the brain has been kept in strong formalin, as directed, it will have been hardened and will be in good condition for dissection; if, however, its condition is for any reason no longer suitable, a fresh animal must be taken.

Remove all the skin and the thick muscles from the head and the high-arched dorsal portion of the trunk just back of it. With a strong scalpel or scissors cut away the roof of the skull and the dorsal wall of the neural canal of the spinal column. The brain does not nearly fill the cavity of the skull but is surrounded by a granular, fatty tissue; carefully remove this substance and expose the brain.

Study its dorsal surface. It is made up of five divisions. The first and anterior division is the **cerebrum**; it consists of a pair of **hemispheres**, at the anterior ends of which project the **olfactory**

lobes. The third division, or **midbrain**, consists of the paired **optic lobes**, the largest part of the brain, between which and the cerebrum appears a small, median, sunken area, the **diencephalon**, the second division. Projecting dorsally from this division is the long and slender **pineal body**, which is the rudiment of a third optic nerve; it may have been removed in exposing the brain. Back of the optic lobes are the fourth division, the **cerebellum**, and the fifth division, the **medulla oblongata**, which is continuous with the **spinal cord**. Note the longitudinal median groove in the medulla and spinal cord, and the paired lateral swellings, the **restiform bodies**, at the anterior end of the former.

Exercise 11. Draw a dorsal view of the brain on a scale of 3 or 4.

The Vascular System. This is made up of the following organs: (1) the **heart**, which receives venous blood from the tissues and forwards it to the gills; (2) the **arteries**, which carry (*a*) venous blood from the heart to the gills, and (*b*) arterial blood from the gills to the tissues; (3) the **veins**, which carry venous blood to the heart; and (4) the **capillaries**.

The Venous System. Two distinct systems of veins are present: one is composed of the **systemic veins**, which carry blood directly to the heart; the other is composed of those which carry blood first to the liver, and is called the **portal system**.

We shall first study the latter system. Take a fresh animal and open its body cavity by a midventral incision. Cut away both the right and the left body walls between the incision and the air bladder. The **portal system** consists of a pair of **intestinal veins** which lie alongside the intestine, a **splenic vein** from the spleen, several **gastric veins** from the stomach, and a **pneumatocystic vein** from the air bladder, all of which unite to form the single large **portal vein**. This vein passes to the hinder surface of the liver, where it breaks into branches which carry the blood to all parts of that organ.

The veins of this system are often difficult to dissect because of the fat in which they usually lie embedded. First find the two intestinal veins and free them from the fat. Lift up the spleen and the duodenal loop in which it lies and find the point of union

of these two veins; find also the splenic vein, the gastric veins from the stomach proper and the pyloric appendages, and the pneumatocystic vein from the air bladder. Note the exact arrangement of these veins; note also the branching of the portal vein on the hinder surface of the liver.

Exercise 12. Draw a semidiagrammatic view of the portal system.

The Heart and the Pericardial Space. Cut away all the muscles between the gills, being very careful not to injure the heart or the artery which issues from its forward end; the pericardial cavity will be thus exposed.

The **heart** in fishes stands in close relation to the gills, and lies in the posteroventral portion of the head between them. It is made up, as we have seen, of three parts: the large muscular **ventricle**, the deep-red **auricle**, and the **sinus venosus**, the vessel which lies across the hinder end of the pericardial space. Blood is brought from the various tissues to the sinus venosus by the veins, from which it flows into the auricle, and from it into the ventricle.

The ventricle sends the blood forward into the **bulbus arteriosus**, a thick-walled vessel in front of the ventricle, which is the beginning of the aorta. The muscular walls of the bulbus are highly elastic, and when they are distended they exert a constant pressure upon the blood which is passing through it; the blood thus flows forward in a constant stream and without pulse beats.

Exercise 13. Draw a semidiagrammatic view of the pericardial cavity with the heart and the bulbus arteriosus.

The Arterial System.[1] The forward continuation of the bulbus arteriosus forms the **ventral aorta.** This vessel sends off four pairs of **afferent branchial arteries** which carry blood to the gills. Four pairs of **efferent branchial arteries** then run

[1] The ventral aorta and afferent branchial arteries may be injected through the bulbus arteriosus. In order to inject the remainder of the arterial system, cut off the tail a short distance in front of the caudal fin and inject forward in the caudal artery. This is the uppermost of the two vessels which lie in the canal formed by the bony arches on the ventral side of the spinal column.

from the gill arches dorsally to the median plane, where they form the **dorsal aorta.**

Springing from the dorsal end of the first (anterior) efferent branchial artery, on each side, is the large **carotid artery**, which supplies the head; it soon divides into two branches, which pass above and below the eye. The dorsal aorta passes along the dorsal side of the body cavity, just beneath the spinal column, to the posterior end of the body; in the caudal region it becomes the **caudal artery** and lies in the ventral arches of the vertebræ. It gives off the paired **spinal arteries** along its entire course; the **cœliac artery**, a large median vessel which leaves the aorta a short distance back of the branchial arteries and, breaking up into a number of branches, supplies the digestive tract, air bladder, and genital glands; and the two **subclavian arteries**, which leave the aorta just back of the cœliac artery and go to the pectoral fins.

First study the ventral aorta and the afferent branchial arteries. Entirely remove the lower jaw and the left operculum, but do not disturb the gill arches; with scissors cut off the gills from the arches. Follow the ventral aorta from the bulbus arteriosus forward between the ventral ends of the gill arches. Find the points where the four afferent arteries on the left side leave the aorta, and trace the course of each along the hinder side of the gill arches; the transparency of the skin covering the gill arches permits this to be done easily.

The remaining arteries will be studied after the veins.

Exercise 14. Draw the arteries just observed.

The Venous System (*Continued*).[1] The following are the systemic veins, which carry blood directly to the heart. The short **hepatic vein** enters the sinus venosus in the median plane. Press the liver away from the false diaphragm and find it. Joining each end of the transverse sinus venosus is a large and conspicuous

[1] The veins are easily studied without injection, as the death of the animal leaves them filled with blood. If it is wished to inject them, however, this may be done through the caudal vein, which is the lowermost of the two vessels in the ventral canal of the vertebral column.

duct, or sinus, called the **Cuvierian duct**. The two Cuvierian ducts lie along the anterior end of the abdominal cavity, parallel with each other and just in front of the liver, between the sinus venosus and the head kidney. Inasmuch as the head kidney is dorsal in position and the sinus venosus ventral, the Cuvierian ducts have an almost vertical position in the body. Trace these vessels from the sinus venosus dorsally; they will be found just behind the posterior gill arch. The dorsal ends of these two ducts are connected by a horizontal sinus which lies just beneath the spinal column.

Two pairs of prominent veins, the **jugulars**, or **anterior cardinals**, and the **posterior cardinals**, bring blood from the anterior and the posterior portions of the body, respectively, to the horizontal sinus of the Cuvierian ducts. Just before joining the sinus the two jugulars unite and form a median vein; the two posterior cardinals also unite and form a median vein.

The two posterior cardinals are large and prominent veins and lie just beneath the vertebral column, partly embedded in the kidneys; the dorsal aorta lies between them. The **left cardinal** is much larger than the right, and much longer, and begins its course at the posterior end of the body as the **caudal vein**; this vein lies in the ventral arches of the spinal column and receives the paired **spinal veins**.

In the trunk region it receives the **left spinal** and **renal veins**. The **right cardinal** begins its course in the hinder part of the body cavity and receives the **right spinal** and **renal veins**. Find the cardinals in the mass of the kidneys and trace them forward to the median cardinal and the Cuvierian ducts.

Find the median jugular vein and trace it and the two jugulars and their branches as far as possible.

Entering the horizontal sinus are three additional veins. Two of these are the small, paired **subclavian veins**, which bring blood from the pectoral fins; the third is the **intestinal vein**, which brings blood from the stomach, intestine, and genital organs. Follow the course of these veins and their branches.

Exercise 15. Draw a diagram of the venous system, so far as observed.

The Arterial System (*Continued*). We shall now study the efferent branchial arteries and the dorsal aorta and its branches. The afferent arteries have already been seen; the efferent arteries lie immediately posterior to them on the gill arches. Make a cross section of a gill arch and note these two arteries; the afferent is the larger of the two. Remove the ventral wall of the pharynx and the heart. Dissect away the mucous membrane which covers the roof of the mouth and pharynx. Trace the efferent arteries dorsally to the dorsal aorta. Follow the aorta and the arteries which branch from it, as already explained (see page 211).

Exercise 16. Draw a diagram showing the efferent branchial arteries, the dorsal aorta and its branches, so far as observed. Carefully label all.

Exercise 17. Draw a diagram of the entire vascular system.

The Body Muscles. Skin the side of the body. Note the great muscle which forms the entire side and extends from the head to the caudal fin. This complex muscle is made up of a succession of muscle segments, which are separated from one another by connective-tissue septa. Each muscle segment is a plate, between two septa, and consists of parallel fibers which run across from one septum to the other. Note the zigzag shape of the edge of a muscle segment, as it appears on the surface of the body; note also that each muscle segment may be divided into a dorsal and a ventral half.

Exercise 18. Make an outline of the fish and draw in it a few of the muscle segments and septa.

Cut the tail off an inch or two behind the anus and study the cut surface. The muscle segments appear here in groups of concentric circles. This appearance is due partly to the fact that the inner edge of each muscle segment, which is attached to the spinal column and to its dorsal and ventral processes, is much anterior in position to the outer edge which appears on the surface, and also partly to the zigzag shape of the muscle segments. Cut horizontal and dorsoventral sections of the muscles and prove this.

Observe the other structures in the cross section: the skin with the scales and the lateral line, and the spinal column with the neural arch on its dorsal side and the hæmal arch on its ventral side, the former containing the spinal cord and the latter the caudal artery and vein.

Exercise 19. Draw the cross section.

The Skeletal System. The skeleton of the fish is made up of two distinct portions, the **exoskeleton** and the **endoskeleton.** The former is of dermal origin and consists of the scales and the teeth. The scales are embedded in the dermis, or inner layer of the skin; covering them on the outside is a thin layer of the dermis and all the epidermis, which, however, are often broken through by the sharp posterior tips of the scales.

Pull out several scales. Note the parallel lines of growth.

Exercise 20. Make a sketch of a scale.

The **endoskeleton** forms the bony and cartilaginous framework of the body. It may be divided into (1) the **axial skeleton,** which includes the skull and the vertebral column, with the ribs; and (2) the **appendicular skeleton,** which includes the skeleton of the paired and the median fins.

To prepare the endoskeleton for study remove all the viscera; immerse the animal in hot water in order to soften the muscles, and then carefully remove them from the skeleton. Separate the bones from one another as little as possible at first, but leave enough of the ligaments to bind them together. Be very careful not to remove any of the bones of the head, some of which are small and easily lost. If any of the bones are removed from the skeleton in preparation, they must be carefully preserved. It is of great practical use to have a dried skeleton at hand for comparison during the dissection. It is not necessary that this skeleton be thoroughly cleaned and mounted, but any skeleton that has been dried after the muscles have been removed will answer the purpose.

The Axial Skeleton. The Vertebral Column and the Ribs. The vertebral column consists of a succession of bony vertebræ closely

connected by intervertebral ligaments. They are deeply biconcave; the two concavities are joined by a central canal and all these spaces are filled with the jellylike notochord. The notochord thus forms a continuous structure which runs the length of the vertebral column.

The vertebral column may be divided into two regions: the **trunk region**, in which ribs are present, and the **caudal region**, in which they are absent. Each **trunk vertebra** is composed of a biconcave **body**, or **centrum**, from the dorsal side of which arises the **neural arch**, and from the ventrolateral side of which projects a pair of long, curved **hæmal processes**, which form the **ribs**. The neural arch is composed of a pair of **neural processes** and a long, median **neural spine**; it incloses the spinal cord.

The **ribs** are long, slender bones which form extensions of the hæmal processes. The ribs of teleosts are not homologous to those of the higher vertebrates, but represent the distal ends of the hæmal processes. Extending from the ribs is also a series of long, slender bones which lie in the muscle segments and may be homologous to the ribs of the higher vertebrates; they are called the **intermuscular bones**.

The **caudal vertebræ** differ from the others in that the hæmal processes meet in the midventral plane and unite in a hæmal spine, forming thus the **hæmal arch**, and inclosing a space in which lie the caudal vein and artery; they do not bear ribs.

The hæmal processes of the caudal vertebræ are thus homologous to the ribs of the trunk region. This homology is easily seen by following the hæmal processes forward from the caudal region: at the point where the two regions meet the caudal hæmal processes separate from each other and become ribs.

Count the trunk vertebræ and caudal vertebræ. Note how the former grade into the latter. The spinal column ends posteriorly with a fan-shaped bone called the **urostyle**.

Exercise 21. Draw a posterior and also a side view of one of the trunk vertebræ; draw the same views of a caudal vertebra.

Make a sagittal section of a vertebra. Examine the concavities with the aid of a lens and note the lines of growth. The centrum

increases in size by the addition of successive layers of bone to the outside, each of which is a little larger than the previous one and hence overlaps it; the biconcave shape is the result of this method of growth.

Exercise 22. Draw the section on a large scale showing these features.

The Skull.[1] The skull is composed of two portions: the **cranium**, which protects the brain and the special sense organs; and the **visceral skeleton**, which surrounds the anterior end of the alimentary canal and consists of the framework of the jaws and gill arches. These two portions of the skull have had a very different origin and are different in character and appearance. The cranium forms the entire dorsal half of the skull, and its constituent bones and cartilages are for the most part immovably knit together, so that they form a single compact whole. The visceral skeleton forms the ventral half of the skull, and its bones and cartilages are mostly loosely joined with one another and with the cranium.

The Visceral Skeleton. Without at first removing any of its parts, we shall now study the skeleton of the jaws and the gill arches. The visceral skeleton is made up of a series of seven arches called the **visceral arches**, which surround the mouth and pharynx. Each visceral arch is a paired structure consisting of a right and a left side which meet in the midventral plane. Each side is also made up of several segments which fall approximately into a dorsal and a ventral half.

The visceral arches may be divided into two groups: an **anterior group**, consisting of the first two arches, which form the skeleton of the jaws, the tongue, and the gill cover; and a **posterior group**, consisting of the last five arches, which support the gills and are called the gill or branchial arches. Identify these two groups.

We shall first study the anterior group. The first visceral arch is the **mandibular arch**. The dorsal and ventral halves of it, to-

[1] For a study of the skull a large fish like a cod is a much more convenient object than a perch.

gether with certain other bones, form the skeleton of the upper jaw, the roof of the mouth, and the lower jaw. The second visceral arch is the **hyoid arch**, the dorsal half of which enters into relation with the mandibular arch and becomes the suspensorium of the jaws, — that is, the connecting link between them and the cranium,— and the ventral half of which forms the support of the tongue and bears the opercular bones and the branchiostegal rays.

The Mandibular Arch. Identify the following bones forming the lower jaw, the ventral half of this arch. At its proximal end is the large **articular bone**, by means of which it articulates with the quadrate bone of the upper jaw. The forward and middle surfaces of the lower jaw are formed on each side by the large **dentary bone**, which bears teeth. A small additional bone, the **angular**, is present at the hinder end of the jaw.

Identify the bones of the upper jaw. Forming the forward end and the lateral margins of this jaw are two pairs of bones, the **premaxillæ** and the **maxillæ**. The former bear teeth and meet each other in the middle line in front; the latter are without teeth, being a pair of flattened rods back of the premaxillæ, with which their anterior ends articulate.

The hinder end of the upper jaw is made up of a series of paired bones. The **quadrate bone** is a large, triangular bone at the hinder end of the upper jaw on each side, with which the lower jaw articulates. The **metapterygoid** is a large bone lying just above the quadrate and back of the orbit. The **ectopterygoid** is an elongated bone which projects in front of the quadrate. The **endopterygoid** is a thin plate above the anterior end of the ectopterygoid and forming a part of the roof of the mouth. In front of the last two bones is the **palatine**, which helps form the roof of the mouth and bears teeth.

Surrounding the orbit and forming its margin on all except the dorsal side is a row of bones called the **suborbitals**, which are very easily lost in the cleaning. The most anterior one is a large bone between the orbit and the maxilla, on the surface of which will be seen radiating canals belonging to the lateral-line system of sensory canals.

The Hyoid Arch. The dorsal half of this arch forms the suspensorium. It is formed by the **hyomandibular** and the **symplectic bones.** The former is a large bone which extends from the cranium ventrally, back of the metapterygoid to the symplectic; the latter is a small bone which lies just dorsal to the hinder end of the quadrate; the jaws are thus joined with the cranium.

The ventral half of the arch is formed by a row of bones, on each side, which extend ventrally from the junction of the symplectic and the hyomandibular and are called collectively the **hyoid bones.** These bear the branchiostegal rays. In the middle area between the right and left sides of the hyoid arch is the **basihyal bone**, which supports the tongue.

Articulating with both the dorsal and ventral halves of the hyoid arch on each side are bony plates and rods which support structures guarding the openings of the gill slits: these are the **opercular bones** and the **branchiostegal rays.** There are four opercular bones: the **preopercular** lies along and back of the hyomandibular and symplectic bones; the **opercular** is a broad bone just back of the preopercular, the hinder border of which is drawn out into a long spine; the **interopercular** and **subopercular** lie along the ventral borders of the preopercular and the opercular respectively.

Articulating with the ventral half of the hyoid arch are seven slender arched bones, the **branchiostegal rays**, which support the branchiostegal membrane.

Exercise 23. Draw a semidiagrammatic view of the side of the skull on a scale of 2, and carefully label all the bones just mentioned.

Disarticulate and remove the five gill arches and the hyoid arch from the body. In the midventral area and joining these arches is a row of median bones called the **copulæ**; the copula of the hyoid arch is the basihyal, which supports the tongue and has already been described. Note the **gill rakers**, the row of short processes which spring from the inner surface of the gill arches; they act as strainers which permit water to pass through the gill slits but keep solid objects out of them. Note **gill rays**, which are on the outer surface of the arches and support the gills.

Exercise 24. Make a drawing of the ventral aspect of the gill and hyoid arches on a scale of 2; carefully label their various parts.

Remove the bones of the visceral skeleton and study the cranium.

The **cranium** is a complicated structure, made up of a large number of bones and cartilages. The bones are so tightly bound together that the sutures are often indistinguishable until the skull has been soaked a long time or boiled in a solution of dilute caustic potash.

Two distinct regions are present in the cranium: (1) the **cranium proper**, which is the brain case and comprises the bones and cartilages in the medial portions of the skull; and (2) the **capsules** of the **special sense organs**, which protect the optic, auditory, and nasal organs.

Observe the general character of the **cranium**. Note the small brain cavity and the **foramen magnum**, the opening at the hinder end of the cranium by which the spinal cord enters it. Note the **orbit**, which occupies a large space on the side of the cranium; the portion of the cranium in front of it forms the **nasal capsule**; that back of it on each side is the **auditory capsule**. Note the two flat spines which project back of the auditory capsule on each side.

Study the posterior aspect of the cranium. The hinder end is formed of four **occipital bones**. The **basioccipital** is ventral; its concave posterior surface articulates with the centrum of the first vertebra. The two **exoccipitals** inclose the foramen magnum between themselves; each bears a broad articular surface which meets a corresponding one on the neural arch of the first vertebra. The foramen of the vagus nerve is in the exoccipital on each side. The **supraoccipital** is dorsal and bears a broad median spine. On each side of these bones and forming the posterolateral part of the cranium is the auditory capsule.

Exercise 25. Draw the hinder end of the skull on a scale of 2, showing outlines of these bones.

Study the dorsal aspect of the cranium. Extending in front of the supraoccipital are the two large **frontal bones**; these form

the greater part of the roof of the skull and the medial walls of the orbits. Immediately back of the frontal bone on each side is the small, irregular **parietal**.

The **auditory capsule** is formed of an intricate complex of bones at the posterolateral corner of the skull. From the hinder end of the capsule two prominent spinelike processes project; these processes on the two sides, together with the median supraoccipital spine, form the five prominent projections at the hinder end of the skull.

Of the two lateral processes the more dorsal is the **epiotic process**; it is formed by the small **epiotic bone**, which lies lateral to the supraoccipital and behind the parietal. The more ventral process is the **parotic process**. It is formed by two bones, the more dorsal being the **pterotic**, the more ventral the **opisthotic**; the latter contains the foramen of the glossopharyngeal nerve. Directly in front of the opisthotic is the **proötic bone**, through the anterior border of which go the trigeminal and facial nerves, and directly above which is the **sphenotic**. These five **otic bones** form the auditory capsule.

Just in front of the proötic and sphenotic are two bones, the **orbitosphenoid** and the **alisphenoid**, the former being the more ventral of the two; they belong to the cranium proper, lie in the lateral wall of the brain case, and are not seen from above.

In front of the frontals and forming the anterior end of the cranium are the paired **nasals**, which form the roof of the nasal capsule.

Exercise 26. Draw the dorsal aspect of the cranium on a scale of 2.

Study the ventral aspect. Three bones form the medial portion of the ventral wall of the cranium: the **basioccipital** at the hinder end, the **vomer** at the forward end, and the long, slender **parasphenoid**, or **parabasal**, between. The vomer bears teeth and forms the ventral wall of the nasal capsule.

In front of the orbits and directly above the vomer are the **median ethmoid** and the two **lateral ethmoids**, which form the anterior end of the cranium proper and the hinder end of the nasal capsules.

The cranium, as we have already seen, is composed of the cranium proper and the special-sense capsules. The former, which is the brain case, contains the following bones: the occipitals, parietals, frontals, sphenoids, ethmoids, and parabasal. The sense capsules inclose the auditory, optic, and olfactory organs. The auditory capsule is made up of the otic bones. The optic capsule does not ossify, but remains largely membranous; the sclera of the eyeball, however, contains cartilage, and the suborbitals appear around the orbit. The nasal capsule contains the nasals and the vomer; the ethmoids also enter into relations with the hinder part of it.

Exercise 27. Draw the ventral aspect of the cranium on a scale of 2, showing outlines of the bones.

Exercise 28. Draw the lateral aspect.

Boil the cranium until the bones can be separated from one another, and study them carefully.

The Appendicular Skeleton. Four **median fins** are present: an anterior and a posterior dorsal fin, a ventral fin, and a caudal fin. The framework of the two dorsal fins and that of the ventral fin are essentially alike; each consists of a series of elongated bones, the **basals** and **radials**. The former are long, flattened plates which lie embedded between the muscles of the right and left sides of the body, alternating with the hæmal and neural spines. Articulating with the outer end of each of these bones is a radial, or fin ray, a straight, bony rod. Note the two kinds of fin rays, the sharp, stiff ones, and the jointed, flexible ones. The anterior basal does not bear a radial. The caudal fin is without basals, the radials joining directly with the urostyle and the neural and hæmal spines.

Exercise 29. Draw the skeleton of a dorsal fin and that of the caudal fin.

The Paired Fins. The **pectoral fin** consists of about fifteen fin rays and four small basals, the latter articulating with the **pectoral girdle**. This structure is formed of several bones, of which two articulate with the basals, the former of these bones being

dorsal to the latter. In addition to these are a number of bones which join the fin with the cranium.

Exercise 30. Draw the pectoral fin and girdle.

The Ventral, or Pelvic, Fins. Each of these consists of about five radials. At their proximal ends they articulate with a large plate which represents the fused basals. These two plates lie alongside of each other in the median area; no pelvic girdle is present.

Exercise 31. Draw the pelvic fins.

APPENDIX

A SYNOPSIS OF THE CLASSIFICATION OF ANIMALS

PHYLUM I. PROTOZOA

Single-celled animals, aquatic and microscopic.

Class 1. ***Sarcodina.*** Protozoans with more or less protractile pseudopodia.

Order 1. Rhizopoda. Pseudopodia without axial filament and usually very retractile. Ex. Amœba.

Order 2. Heliozoa. Fresh-water Sarcodina with siliceous skeleton and raylike pseudopodia, each with an axial filament. Ex. Actinospherium.

Order 3. Radiolaria. Marine Sarcodina with siliceous skeleton. Ex. Polycystina.

Class 2. ***Mastigophora*** (Flagellata). Protozoans with one or more vibratile flagella. Ex. Euglena.

Class 3. ***Sporozoa.*** Protozoans which are internal parasites and have no locomotory organs as adults. Ex. Gregarina.

Class 4. ***Infusoria.*** Protozoans with cilia or sucking tentacles.

Order 1. Ciliata. Ciliate infusorians. Ex. Paramecium.

Order 2. Suctoria. Infusorians with sucking tentacles. Ex. Acineta.

PHYLUM II. PORIFERA

Sessile, mostly colonial animals without specialized organs or tissues; body wall pierced by numerous pores or canals and usually stiffened by either calcareous or siliceous spicules and either with or without spongin fibers.

Class 1. ***Calcarea.*** Sponges with calcareous spicules and of simple structure. Ex. Grantia.

Class 2. ***Hexactinellida.*** Glass sponges with six-rayed siliceous spicules. Ex. Euplectella.

Class 3. ***Demospongiæ.*** Massive sponges with either siliceous spicules or spongin fibers or both. Ex. Spongilla.

PHYLUM III. CŒLENTERATA

Radiate animals with a single but often branched internal cavity and no cœlom.

Subphylum I. **Cnidaria.** Cœlenterates provided with nettle cells.

Class 1. ***Hydrozoa*** (Hydromedusæ). Hydroid polyps and jellyfish, the former without mesenterial ridges and the latter with a velum.

Order 1. Hydrariæ. Fresh-water hydroids of simple structure. Ex. Hydra.

Order 2. Hydrocorallinæ. Coral-like marine hydrozoans. Ex. Millepora.

Order 3. Tubulariæ. Hydroids without hydrotheca; medusæ with gonads on the manubrium. Ex. Pennaria.

Order 4. Campanulariæ. Hydroids with hydrotheca; medusæ with gonads on the subumbrella. Ex. Obelia.

Order 5. Trachomedusæ. Hydroids (when present) minute and of simple structure; medusæ usually large with gonads on the subumbrella. Ex. Gonionemus.

Order 6. Narcomedusæ. Hydroids wanting; medusæ with lobed rim. Ex. Cunina.

Order 7. Siphonophora. Free-swimming colonial hydrozoans. Ex. Physalia.

Class 2. ***Scyphozoa*** (Scyphomedusæ). Hydroids and jellyfish, the former with mesenterial ridges and the latter without a velum and often of large size. Ex. Aurelia.

Class 3. ***Anthozoa.*** Sea anemones and corals; solitary or colonial polypoid cnidarians without medusoid generation.

Order 1. Alcyonaria. Anthozoans with eight mesenterial ridges and eight pinnate tentacles. Ex. Corallium.

Order 2. Zoantharia. Anthozoans with numerous mesenterial ridges and numerous simple tentacles. Ex. Metridium.

Subphylum II. **Ctenophora.** Cœlenterates with eight bands of ciliated ridges on outer surface. Ex. Mnemiopsis.

PHYLUM IV. VERMES

The lower worms. Animals of primitive structure and without paired locomotory appendages or distinct head.

Subphylum I. **Platyhelminthes.** Flatworms; no anus present in most forms and body cavity filled with a vesicular connective tissue called parenchyma.

Class 1. ***Turbellaria.*** Mostly free-living flatworms with ciliated outer surface. Ex. Planaria.

Class 2. ***Trematodes.*** Flukes. Small parasitic flatworms with mostly a branched digestive tract and an anterior mouth. Ex. Fasciola.

Class 3. ***Cestodes.*** Tapeworms. Elongated, usually segmented parasitic flatworms without digestive tract. Ex. Tænia.

Class 4. ***Nemertea.*** Nemertean worms. Elongated, mostly free-swimming flatworms with a protrusile proboscis and a cilated outer surface. Ex. Cerebratulus.

Subphylum II. **Nemathelminthes.** Roundworms or threadworms; mostly parasitic. Ex. Ascaris.

Subphylum III. **Trochelminthes** (Rotifera). Minute, aquatic worms with mouth surrounded by cilia. Ex. Rotifer.

Subphylum IV. **Bryozoa.** Minute, sessile, colonial animals with a ridge bearing ciliated tentacles around the mouth. Ex. Bugula.

Subphylum V. **Brachiopoda.** Sessile, marine, mollusk-like animals with a dorsal and a ventral shell. Ex. Terebratulina.

Subphylum VI. **Phoronidea.** Sessile, marine worms living in tubes and with a tentacular ridge around the mouth. Ex. Phoronis.

Subphylum VII. **Chætognatha.** Minute, transparent, marine worms with a slender body, two or three pairs of horizontal fins, and paired prehensile bristles around the mouth. Ex. Sagitta.

Subphylum VIII. **Sipunculoidea.** Elongated, marine worms, the anterior portion of which can be invaginated and is usually surrounded by tentacles. Ex. Sipunculus.

PHYLUM V. ANNELIDA

The higher worms. Elongated, segmented worms which have paired, unsegmented appendages, and a usually distinct head.

Class 1. ***Archiannelida.*** No parapodia or setæ. Ex. Polygordius.

Class 2. ***Chætopoda.*** With setæ, segmentally arranged.

Order 1. Polychæta. Mostly marine chætopods with parapodia on which are numerous setæ. Ex. Nereis.

Order 2. Oligochæta. Earthworms. Mostly fresh-water or land chætopods without parapodia and with few setæ. Ex. Lumbricus.

Class 3. ***Hirudinea.*** Leeches. Annelids with a sucker at each end and no appendages or setæ. Ex. Hirudo.

Class 4. ***Myzostomida.*** Disk-shaped parasites of echinoderms with five pairs of parapodia. Ex. Myzostoma.

PHYLUM VI. ARTHROPODA

Externally segmented animals with segmented appendages.

Class 1. ***Crustacea.*** Aquatic, gill-bearing arthropods; two pairs of antennæ present.

Division 1. *Entomostraca*. Small, simply constructed crustaceans with a variable number of body segments and without abdominal appendages.

Order 1. Phyllopoda. Entomostracans with flat, leaflike appendages.

Suborder 1. Branchiopoda. Elongated phyllopods with segmented body. Ex. Branchipus.

Suborder 2. Cladocera. Laterally compressed phyllopods, the body of which is not distinctly segmented and is inclosed in a bivalve shell; second pair of antennæ are swimming organs and project from the shell. Ex. Daphnia.

Order 2. Copepoda. Elongated entomostracans with distinctly segmented body and without gills; the female often carries one or two egg sacs. Ex. Cyclops.

Order 3. Ostracoda. Minute, laterally compressed entomostracans with entire body inclosed in a bivalve shell. Ex. Cypris.

Order 4. Cirripedia. Sessile, hermaphroditic entomostracans with body inclosed in a calcareous shell; barnacles. Ex. Lepas.

Division 2. *Malacostraca*. Crustaceans with a constant number (twenty) of body segments and nineteen pairs of appendages; abdominal appendages present.

Subdivision 1. Phyllocarida. Primitive malacostracans with carapace and with leaflike thoracic feet. Ex. Nebalia.

Subdivision 2. Arthrostraca. Malacostracans with usually seven free thoracic body segments, and with sessile eyes.

Order 1. Amphipoda. Laterally compressed arthrostracans with gills on thorax. Ex. Gammarus.

Order 2. Isopoda. Dorsoventrally depressed arthrostracans with gills on the abdomen. Ex. Oniscus.

Subdivision 3. Thoracostraca. Malacostracans with carapace covering the head and all or some of the thorax, and with stalked eyes.

Order 1. Schizopoda. Small thoracostracans with carapace covering entire thorax, and with one pair of maxillipeds. Ex. Mysis.

Order 2. Stomatopoda. Thoracostracans with three free thoracic body segments and large abdomen. Ex. Squilla.

Order 3. Cumacea. Small thoracostracans with reduced carapace. Ex. Diastylis.

Order 4. Decapoda. Large thoracostracans with carapace covering entire thorax, and with three pairs of maxillipeds.

Suborder 1. Macrura. Elongated decapods with large abdomen. Ex. Homarus.

Suborder 2. Brachyura. Broad decapods with reduced abdomen. Ex. Cancer.

Class 2. ***Arachnoidea.*** Arthropods lacking antennæ and with body usually consisting of cephalothorax and abdomen.

Division 1. *Xiphosura.* Large marine arachnoideans with a long, spike-like telson. Ex. Limulus.

Division 2. *Arachnida.* Usually air-breathing arachnoideans with six pairs of appendages.

Order 1. Scorpionida. Large arachnids with a long, segmented abdomen ending in a poisonous sting. Ex. Scorpio.

Order 2. Palpigradi. Minute arachnids with a long, segmented caudal filament. Ex. Kœnenia.

Order 3. Pedipalpi. Arachnids with a constriction between the cephalothorax and the segmented abdomen. Ex. Thelyphonus.

Order 4. Solifugæ. Arachnids with a constriction between the head and thorax. Ex. Galeodes.

Order 5. Pseudoscorpionida. Arachnids without a constriction between cephalothorax and abdomen; pedipalps chelate and very long. Ex. Chelifer.

Order 6. Phalangida. Arachnids with extremely long, slender legs and a segmented abdomen. Ex. Phalangium.

Order 7. Araneæ. Spiders. Arachnids with a constriction between the cephalothorax and the unsegmented abdomen. Ex. Agelena.

Order 8. Acarina. Mites. Arachnids with body not divided into cephalothorax and abdomen, and unsegmented. Ex. Hydrachna.

Order 9. Linguatulida. Parasitic arachnids with ringed, vermiform body. Ex. Pentastomum.

Order 10. Tardigradi. Minute, aquatic arachnids. Ex. Macrobiotus.

Order 11. Pycnogonida. Sea spiders. Marine arachnids with very long legs. Ex. Pallene.

Class 3. ***Tracheata.*** Air-breathing arthropods with one pair of antennæ.

Division 1. *Onychophora.* Wormlike tracheates with indistinctly segmented body and appendages. Ex. Peripatus.

Division 2. *Myriapoda.* Wormlike tracheates with distinctly segmented body and appendages.

Order 1. Progoneata. Body mostly cylindrical and with two pairs of legs to a segment. Ex. Julus.

Order 2. Chilopoda. Centipeds. Flattened myriapods with one pair of legs to a segment. Ex. Lithobius.

Division 3. *Insecta.* Insects. Tracheates with body divided into head, thorax, and abdomen; with three pairs of legs and usually two pairs of wings.

Order 1. Aptera. Minute, wingless insects without metamorphosis. Ex. Lepisma.

Order 2. Pseudoneuroptera. Insects with two pairs of net-veined wings, biting mouth parts, and incomplete metamorphosis, Ex. Dragon fly.

Order 3. Orthoptera. Insects with two pairs of wings (the first pair being usually parchment-like), biting mouth parts, and incomplete metamorphosis. Ex. Grasshopper.

Order 4. Neuroptera. Insects with two pairs of net-veined wings, biting mouth parts, and complete metamorphosis. Ex. Ant lion.

Order 5. Coleoptera. Beetles. Insects with two pairs of wings (of which the first pair are elytra), biting mouth parts, and complete metamorphosis. Ex. Potato beetle.

Order 6. Hemiptera. Bugs. Insects with two pairs of wings, or wingless, with sucking mouth parts in form of a jointed proboscis, and incomplete metamorphosis. Ex. Aphis.

Order 7. Lepidoptera. Butterflies and moths. Insects with two pairs of scale-covered wings, with biting or sucking mouth parts in form of a long, unjointed proboscis, and complete metamorphosis. Ex. Bombyx.

Order 8. Diptera. Insects with one pair of wings, sucking mouth parts, and complete metamorphosis. Ex. House fly.

Order 9. Hymenoptera. Insects with two pairs of wings, biting and licking mouth parts, and complete metamorphosis. Ex. Bee.

PHYLUM VII. MOLLUSCA

Animals without paired locomotory appendages and with a soft, unsegmented body which is usually inclosed in a calcareous shell.

Class 1. ***Amphineura.*** Symmetrical mollusks without a shell or with one composed of eight pieces in a longitudinal row. Ex. Chiton.

Class 2. ***Scaphopoda.*** Symmetrical mollusks with a cylindrical shell. Ex. Dentalium.

Class 3. ***Gastropoda.*** Snails. Mollusks with an asymmetrical, spiral shell and a single mantle cavity.

Order 1. Opisthobranchiata. Marine snails with posterior gills. Ex. Æolis.

Order 2. Pulmonata. Fresh-water and land snails, without gills but with lungs. Ex. Helix.

Order 3. Prosobranchiata. Mostly marine snails with anterior gills. Ex. Fulgur.

Class 4. ***Pelecypoda.*** Symmetrical mollusks with a bivalve shell and paired mantle cavities. Ex. Unio.

Class 5. ***Cephalopoda.*** Mollusks with a large head, which bears a number of long arms, and with a single mantle cavity.

Order 1. Tetrabranchiata. Cephalopods with four gills and a large convoluted shell. Ex. Nautilus.

Order 2. Dibranchiata. Cephalopods with two gills and either eight or ten arms; shell, when present, concealed in the mantle. Ex. Loligo.

PHYLUM VIII. ECHINODERMATA

Radially symmetrical animals with calcareous plates or spicules in the body wall.

Class 1. ***Crinoidea.*** Sea lilies. Echinoderms which are sessile throughout life or only as larvæ. Ex. Comatula.

Class 2. ***Asteroidea.*** Starfish. Flattened, star-shaped echinoderms with an ambulacral furrow on the under side of each ray. Ex. Asterias.

Class 3. ***Ophiuroidea.*** Brittle stars. Flattened echinoderms with long, vibratile arms and without ambulacral furrows. Ex. Amphiura.

Class 4. ***Echinoidea.*** Sea urchins. Spheroidal or flattened echinoderms without arms. Ex. Arbacia.

Class 5. ***Holothurioidea.*** Sea cucumbers. More or less wormlike echinoderms with oral tentacles. Ex. Synapta.

PHYLUM IX. CHORDATA

Animals with a dorsal central nervous system, an internal skeletal system, consisting in the simplest cases of the notochord, and paired pharyngeal slits and arches.

Subphylum I. **Enteropneusta.** Wormlike chordates with a large proboscis in front of the mouth. Ex. Balanoglossus.

Subphylum II. **Tunicata.** Chordates in which the body is inclosed in a tunic; a large pharyngeal chamber and a ventral heart present.

Class 1. ***Larvacea.*** Minute, free-swimming tunicates with a long tail. Ex. Appendicularia.

Class 2. ***Thaliacea.*** Free-swimming, transparent tunicates. Ex. Salpa.

Class 3. ***Ascidiacea.*** Sessile, saccular tunicates, either simple or colonial. Ex. Molgula.

Subphylum III. **Leptocardia.** Elongated, fishlike chordates, compressed laterally and attenuated at both ends. Ex. Amphioxus.

Subphylum IV. **Vertebrata.** Chordates with distinct head, bearing organs of special sense, with red blood, and usually with two pairs of appendages.

Class 1. ***Pisces.*** Fishes. Aquatic vertebrates which breathe by means of gills, and usually with bony scales and paired fins. Ex. Perca.

Class 2. ***Amphibia.*** Amphibians. Vertebrates with gills during a part or all of their life, and usually with lungs; scales mostly absent. Ex. Rana.

Class 3. ***Reptilia.*** Reptiles. Vertebrates with body covered with horny scales or plates and without gills. Ex. Coluber.

Class 4. ***Aves.*** Birds. Feathered vertebrates whose anterior appendages are wings. Ex. Gallus.

Class 5. ***Mammalia.*** Mammals. Hair-covered vertebrates which suckle their young. Ex. Felis.

GLOSSARY

Abdomen: in invertebrates, the posterior body division; in vertebrates, the ventral area back of the thorax.

Aboral: the side of the body opposite the mouth in a radiate animal.

Aciculum: a chitinous supporting rod in the parapodia of annelids.

Acontia: long threads armed with nettle cells in sea anemones.

Adductor muscle: a muscle which draws an organ toward the axis of the body.

Air sacs: tracheal enlargements in insects.

Algæ: very simple, green plants.

Alimentary tract: the digestive canal, the organ which ingests, digests, and absorbs the food.

Alternation of generations: the alternate succession of sexual and asexual generations in plants and animals.

Alveolus: a pyramidal ossicle which supports one of the five teeth in the dentary apparatus of the sea urchin.

Ambulacral feet: tubular projections with sucker disks at their ends in echinoderms.

Ambulacral groove: the elongated groove on the oral side of the rays of the starfish.

Ambulacral pores: minute openings in the body wall in the starfish and the sea urchin.

Ampulla: a saclike projection of the ambulacral foot in echinoderms.

Anal feelers: paired posterior projections.

Analogous: having a similar function.

Antenna: a segmented sensory appendage on the head of arthropods.

Anterior: at or toward the front end of the body.

Anus: the posterior opening of the digestive canal.

Aorta: a large artery leading directly from the heart.

Appendage: a projection from some part of the body.

Appendix: a short diverticulum of the intestine.

Aristotle's lantern: the dentary apparatus of the sea urchin.

Artery: a blood vessel carrying blood away from the heart to the tissues.

Arthrobranch: a gill attached to the joint between the leg and the body in crustaceans.

Articulate: composed of a series of homologous segments.

Asexual: reproduction by division or budding and not through the agency of the sexes.

Auricle: a chamber of the heart which receives the blood from the veins.
Avicularium: a structure shaped like a bird's head attached to the zoœcium in Bryozoa.

Balancers: the homologues of the metathoracic wings in Diptera.
Bilateral symmetry: having the right and left sides alike.
Bivalve: a shell composed of two distinct and equivalent parts or valves.
Bivium: the two rays of a starfish or a sea urchin which inclose the madreporite between them; the two rays forming the upper side of the holothurian's body.
Blastostyle: the reproductive polyp of a campanularian hydroid.
Body cavity: an internal space in the body in which lie the viscera; the cœlom.
Body wall: the outer portion of the body, which usually bounds the body cavity toward the inside.
Brachial: relating to the arms.
Branchial: relating to the gills.
Branchial heart: a lateral heart in the squid.
Branchiate: bearing gills.
Branchiostegite: a paired lateral fold of the body wall in crustaceans.
Brood sac: a chamber in which the eggs develop in certain crustaceans.
Bud: an outgrowth of an animal which becomes a new individual.

Cæcum: a saclike appendage of the digestive tract.
Calcareous: formed of carbonate of lime.
Carapace: the shell covering a portion or all of the cephalothorax in crustaceans.
Cardo: the basal division of the maxilla in insects.
Cellulose: the woody cell wall of plant cells.
Cephalothorax: a body division formed by the fusion of the head and the thorax in arthropods.
Cercus: a paired projection at the posterior end in certain insects.
Cerebral: relating to the cerebrum, or brain.
Cheliped: the large grasping claw in many crustaceans.
Chitin: a hard and very resistant substance present in the cuticula of arthropods.
Chloragogue cells: glandular cells surrounding the digestive canal of the earthworm.
Chlorophyll: the green coloring matter of plants.
Chromatophores: pigment bodies.
Cilia: the numerous vibratory projections on the surface of certain cells.
Cirrus: a filamentous, sensory appendage of annelids; a protrusile, copulatory organ of flatworms.
Clitellum: a thickened, glandular region on the earthworm which secretes the cocoon.

Cloaca: a tubular or saclike space which receives the discharge of various organs.
Clypeus: a median sclerite in the face of insects just back of the upper lip.
Cnidoblast: a stinging cell in Cnidaria which contains the nematocyst.
Cocoon: a case containing one or more developing animals.
Cœlom: the body cavity.
Collar: the ventral edge of the mantle in gastropods and cephalopods.
Colon: a division of the intestine.
Columella: the axis of a spiral snail's shell; a minute rodlike bone in the ear of frogs.
Compound eye: an eye made up of a number of separate elements, or ommatidia, in arthropods.
Conjugation: the fusion of two protozoans and interchange of nuclear matter.
Connective tissue: a tissue whose principal function is to support and hold in place other tissues and organs.
Coxa: the proximal segment of an insect's or a spider's leg, by which it articulates with the body.
Crop: a dilated portion of the œsophagus.
Ctenidium: a respiratory organ in mollusks.
Cuticula: the outer layer of the integument of most invertebrates.
Cyst: a capsule containing an animal usually in a state of suspended animation.
Cysticercus: a cyst containing a tapeworm scolex.

Dentary apparatus: the five teeth and their supporting structure in the sea urchin.
Development: the series of changes in the early life of any animal by which it passes from the condition of a fertilized egg to that of the adult.
Dimorphism: the condition in which a species exists in two distinct forms, as, for instance, male and female.
Distal: a position away from the point of attachment — opposed to proximal.
Diverticulum: a saclike projection of a tubular organ.
Dorsal: on or toward the back.
Dorsal lamina: a ciliated ridge in the mid-dorsal line of the pharynx in the ascidian.

Ectoderm: the outermost layer of cells in the Porifera and Cœlenterata.
Ectosarc: the outermost layer of nongranular protoplasm in protozoans.
Elytra: the hard wing-covers in beetles.
Embryo: a young animal which is passing through its developmental stages, usually within the egg membranes or in the maternal uterus.
Encyst: the act of an animal in forming a cyst about itself.

Endopodite: the innermost of the two terminal branches of the typical crustacean leg.
Endoskeleton: an internal supporting structure.
Endostyle: a ciliated and glandular groove in the midventral line of the pharynx in ascidians.
Entoderm: the innermost layer of cells in the Porifera and Cœlenterata.
Entosarc: the inner granular protoplasm in protozoans.
Epicranium: the sclerite forming the dorsal, median, and lateral walls of the head in insects.
Epigynum: a cuticular plate covering or accompanying the female genital pore in many species of spiders.
Epiphragma: the disk of calcified slime with which a land snail can close the opening of its shell.
Epipodite: a membranous projection of the protopodite in crustaceans.
Excretion: the elimination of nitrogenous wastes from the body.
Excurrent: passing outward.
Exopodite: the outermost of the two terminal branches of the typical crustacean leg.
Extensor muscle: a muscle that extends an organ.
Extremity: a paired lateral or ventral appendage of the body of an animal, used primarily for locomotion, although in many cases having secondarily some other function.
Exumbrella: the aboral side of a medusa.

Femur: a segment of an insect's or a spider's leg; the thigh bone in vertebrates.
Fertilization: the union of the spermatozoön and the ovum.
Flagellum: a vibratory threadlike projection of certain cells.
Flame cell: the terminal cell of an excretory tubule of flatworms.
Flexor muscle: a muscle that bends an organ.
Food vacuole: a globule of water containing food particles.
Front: the anterior median portion of the epicranium.
Funiculus: a mesenteric strand connecting the stomach pouch with the body wall in bryozoans.
Funnel: the siphon of a cephalopod.

Ganglion: an aggregation of nerve cells.
Gastrolith: a calcareous body sometimes present in the stomach of crustaceans.
Gastrovascular space: the central cavity in Cœlenterata.
Gastrula: a stage in the development of the embryo in which two cell layers only are present, the ectoderm and the entoderm.
Gena: the lateral portion of the epicranium in insects.
Genital plate: a sclerite at the posterior end of the abdomen in the male grasshopper.

Giant fibers: three large fibers in the dorsal portion of the nerve cord in the earthworm.
Gill: an organ for the breathing of air contained in the water.
Gill filament: ciliated vertical ridges on the surface of the gills.
Gizzard: a portion of the alimentary tract with thickened muscular walls; a chewing stomach.
Gland: an organ which produces a secretion.
Glochidium: the larval form of Anodonta and Unio, which lives a parasitic life in the skin of fishes.
Glottis: the opening from the pharynx into the trachea.
Gonotheca: the cuticular outer covering of the blastostyle.
Green gland: the kidney of a malacostracan crustacean.

Hæmal: pertaining to the blood system.
Head: the anterior body division of the higher animals.
Heart: a muscular tubelike or saclike organ which propels the blood.
Hermaphroditic: having the two sexes united in one animal.
Hinge ligament: the flexible portion of a bivalve shell which joins the two valves.
Homologous: having had a similar origin.
Host: the animal which harbors a parasite.
Hydranth: a feeding polyp in a hydroid colony.
Hydrocaulus: the stem of a hydroid colony.
Hydroid: the sessile, asexual generation of the Hydromedusæ.
Hydrorhiza: the rootlike projections of a hydroid colony by which it is attached.
Hydrotheca: the cuticular outer covering of the hydranth in campanularian hydroids.
Hypodermis: the cellular layer which forms the inner portion of the integument of most invertebrates.
Hypopharynx: a median projection from the ventral wall of the pharynx in insects.
Hypophysis: a ventral projection of the brain in vertebrates.
Hypostome: the projection of a hydroid's body which bears the mouth.

Imago: an insect which has completed its metamorphosis; an adult insect.
Incurrent: passing inward.
Integument: the outer covering of an animal.
Interfilamentary connections: cross ridges which join the gill filaments in clams.
Interlamellar partitions: vertical walls which join the two lamellæ of a clam's gills.
Intermediate host: the animal which harbors the larval form of a parasite.
Interray: one of the divisions of the radiate body of echinoderms.
Intestine: a division of the digestive tract.

Kidney: an excretory organ which eliminates nitrogenous wastes from the body.

Labium: the lower lip of insects.
Labrum: the upper lip of insects and of some crustaceans.
Lamella: a leaflike or platelike structure.
Larva: a young animal which has left the egg and is leading a free life, but which has not yet completed its development.
Lateral: a position to the right or left of the median line.
Ligament: a tough connecting band.
Ligula: the anterior portion of the labium in insects.
Lithocyst: a marginal sense organ in certain medusæ.
Liver: a digestive gland.
Lophophore: a circular or horseshoe-shaped ridge bearing tentacles in Bryozoa.
Lumen: the cavity within a tubular organ.

Macronucleus: the large nucleus of an infusorian.
Madreporite: a porous plate through which fluids enter the ambulacral system.
Malpighian tubules: the kidney of insects and certain other arthropods.
Mandible: the anterior pair of mouth parts in arthropods; the lower jaw of vertebrates.
Mantle: the integumental fold in mollusks which secretes the shell.
Manubrium: the projection of a medusa's body which bears the mouth.
Maxillæ: the paired mouth parts immediately behind the mandibles in arthropods; the upper jaw of vertebrates.
Maxillipeds: the anterior thoracic appendages which assist in mastication in crustaceans.
Medusa: a medusoid which becomes a free-swimming jellyfish.
Medusoid: the sexual generation of a hydromedusan.
Megalopa: a larval stage of the crab.
Mentum: a division of the labium in insects.
Mesentery: a lamella which supports some one of the viscera.
Mesothorax: the second thoracic somite in insects.
Metamere: one of the serial, homologous body segments, together with its appendages, which form the body of an articulate animal.
Metamorphosis: the quiescent period in the life of a holometabolic insect during which it changes from a larva to an imago.
Metasoma: the primitive segmented trunk of an articulate animal.
Metastomium: the posterior portion of the prosoma of an annelid.
Metathorax: the third thoracic somite in insects.
Metazoa: the division of the animal kingdom comprising the many-celled animals.

Micronucleus: the smaller of the nuclear bodies in infusorians.
Mother-of-pearl: the inner layer of the shell of mollusks.
Molt: to shed the cuticula or the outer portion of it.
Mouth parts: the masticatory appendages on the head of arthropods.
Mysis stage: a larval form of the lobster.

Nauplius: a larval form of crustaceans.
Nematocyst: the stinging organ in the Cœlenterata which is within the cnidoblast.
Nephridium: a urinary tubule in annelids.
Nephrostome: the ciliated opening of a nephridium into the body cavity.
Nerve commissure: a nerve connecting the two members of a pair of ganglia.
Nerve connective: a nerve connecting two ganglia not of the same pair.
Nettle cell: the stinging organ in the Cœlenterata.
Neuropodium: the ventral division of the parapodium of an annelid.
Nidamental glands: the large glands which secrete the egg capsules in the squid.
Notopodium: the dorsal division of the parapodium of an annelid.
Nucleus: a spheroidal body in a cell, the center of its activities.

Ocellus: a minute, primitive eye.
Ocular plate: the plate at the aboral end of a ray of the sea urchin.
Œsophagus: the gullet, the division of the digestive canal leading from the pharynx to the stomach.
Ommatidium: a single element of the compound eye of an arthropod.
Oœcium: a structure in Bryozoa in which the embryo develops.
Operculum: the flap covering the gill slits in fishes.
Oral: relating to the mouth.
Oral groove: a groove leading to the mouth in ciliate infusorians.
Osculum: the cloacal opening in sponges.
Ossicles: the calcareous plates in the body wall of echinoderms.
Ovarioles: the tubules forming the ovary of an insect.
Ovary: the female sexual gland.
Oviduct: the tube leading from the ovary toward the outside.
Ovipositor: the organ by means of which certain insects deposit their eggs.
Ovum: the female sexual cell, the egg.

Pallial line: the line along which the margin of the mantle is attached to the shell in mollusks.
Pallial sinus: the indentation in the pallial line caused by the insertion of the siphonal retractor muscle.
Palp: a sensory organ near the mouth.
Pancreas: a digestive gland.
Papulæ: the delicate projections of the body wall in the starfish.

Paragnatha: delicate lamellæ just behind the mandibles in the crayfish or the lobster.
Parapodium: the appendage of annelids.
Parasite: an animal which attaches itself to another and lives upon its nutritive fluids.
Parenchyma: a vesicular connective tissue which fills the body cavity of flatworms and leeches.
Parthenogenesis: reproduction by means of unfertilized eggs.
Pectoral: relating to the thorax or breast.
Pedicellariæ: minute pincer-like organs present on the external surface of starfishes and sea urchins.
Pedipalps: the second pair of appendages in the Arachnida.
Pelvic: relating to the region of the hind limbs.
Pen: the shell of the squid.
Pericardium: the membrane surrounding the heart.
Periopods: the thoracic appendages posterior to the maxillipeds in crustaceans.
Periostracum: the outer layer of the molluscan shell.
Periphery: the outer surface of a body.
Periproct: the region immediately around the anus.
Perisarc: the cuticular outer covering of a hydroid.
Peristome: a membrane surrounding the mouth in echinoderms.
Peristomium: the posterior portion of the head in most annelids, consisting of the metastomium and the anterior somites of the metasoma.
Peritoneum: the membrane lining the body cavity.
Pharynx: the division of the alimentary tract immediately back of the mouth.
Plankton: a collective term referring to all small forms of life in the surface waters of the sea or of fresh water.
Planula: the larva of many Cœlenterata.
Pleopod: an abdominal appendage in crustaceans.
Pleurobranch: a gill attached to the body wall in crustaceans.
Plexus: a network.
Podical plates: paired sclerites at the posterior end of the abdomen in certain insects.
Podobranch: a gill attached to the leg in crustaceans.
Polian vesicle: a sac extending from the ring canal in echinoderms.
Polymorphism: the condition in which a species exists in several distinct forms.
Polyp: a sessile individual of any of the lower animals.
Polypide: the soft parts of a bryozoan.
Posterior: at or toward the hinder end of an animal.
Proboscis: a prehensile or sucking organ in certain animals, usually a portion of the pharynx.

Proglottid: a tapeworm segment.
Prosoma: the primitive head of annelids made up of the prostomium and the metastomium.
Prostate gland: the gland which secretes the fluid in which the spermatozoa are suspended.
Prostomium: the anterior portion of the head of annelids.
Prothorax: the first thoracic segment in insects.
Protopodite: the basal segment of a crustacean's leg.
Protractor muscle: a muscle which extends the organ to which it is attached or moves it forward.
Proximal: a position toward the point of attachment — opposed to distal.
Pseudopodium: a retractile process in rhizopods.
Pulsating vacuole: a globule of excretory fluid in many protozoans.
Pulvillus: an adhesive pad on the foot of insects.
Pupa: the stage in the life of a holometabolic insect when it is undergoing its metamorphosis.
Pyrenoids: protein bodies in Euglena producing starch.

Racemose vesicles: minute diverticula of the ring canal in starfishes.
Radial symmetry: having the parts or organs arranged symmetrically about a common center.
Radial tubes: a portion of the gastrovascular space in the medusa.
Radula: the band of calcareous teeth in the pharynx of gastropods and cephalopods.
Ray: one of the main divisions of the radiate body of echinoderms.
Receptaculum seminis: a receptacle for sperm in the female animal.
Rectum: the posterior division of the digestive tract.
Respiratory tree: a branched diverticulum of the rectum in holothurians.
Retractor muscles: muscles which draw in an organ to which they are attached.
Rostrum: a projection of the carapace in crustaceans.

Sagittal: pertaining to a median dorsoventral plane in an animal's body.
Salivary glands: digestive glands at the anterior end of the digestive tract.
Scaphognathite: the elongated epipodite of the second maxilla in certain crustaceans.
Sclerite: a small plate forming a portion of the cuticula of a segment in insects.
Scolex: the anterior end of a tapeworm.
Scutellum: a small sclerite in the tergum of the thoracic segments in insects.
Segment: one of a number of serial divisions of an animal's body or of an organ.
Septum: a plate forming a division wall between two spaces.

Sessile: fixed to one place, without locomotory powers — of an animal; not on a stalk or stem — of an organ.
Seta: a bristle.
Sexual: reproduction through the agency of the two sexes.
Shell gland: the kidney of entomostracans.
Siphon: the organ through which water enters or leaves the mantle cavity in mollusks and ascidians.
Siphonoglyph: a ciliated groove in the angle of the gullet in Anthozoa.
Somite: one of the serial, homologous body segments which form the body of an articulate animal.
Spermatophore: a capsule of spermatozoa.
Spermatozoön: the male sexual cell.
Sperm duct: a duct leading from the testis.
Sperm receptacle: a sac for the storing of sperm in the female animal.
Sperm sac: a sac for the storing of sperm in the male animal, a seminal vesicle.
Sperm sphere: a mass of spermatozoa in the earthworm.
Spicule: a minute, calcareous or siliceous body in sponges and echinoderms.
Spinnerets: the appendages on a spider from which the silk exudes.
Spiracle: an external opening in the tracheal system.
Sporosac: a sessile medusoid, one which remains attached to the parent hydroid.
Sternum: the breastbone.
Stigmata: the respiratory openings in the pharyngeal wall in Molgula.
Stipes: a division of the maxilla in insects.
Stomach: a division of the digestive tract.
Stomach pouch: a diverticulum of the stomach.
Stone canal: a tube joining the madreporite with the ring canal in echinoderms.
Submentum: the basal segment of the labium in insects.
Subneural gland: a glandular body in ascidians.
Subumbrella: the oral surface of a medusa.
Supporting layer: the noncellular layer between the ectoderm and entoderm in Hydrozoa.
Swimmeret: an abdominal appendage of a crustacean, a pleopod.
Symbiotic: the living together of two dissimilar organisms, each being dependent upon the other.
Systemic heart: the median heart of the squid.

Tactile: relating to the sense of touch.
Tarsus: the foot of an insect or a spider; the ankle of vertebrates.
Telson: the terminal segment of a crustacean.
Tentacle: an elongated, unsegmented tactile organ.
Tergum: the dorsal surface.

Terminal: toward or at the posterior or the distal end.
Test: the tunic of the ascidian; the rigid shell of the sea urchin.
Testis: the male sexual gland.
Thorax: the body division of arthropods following the head; the chest of vertebrates.
Tibia: the segment of an insect's leg; a bone in the shank of vertebrates.
Tiedemann's vesicles: minute diverticula of the ring canal of the starfish.
Trachea: a respiratory tube.
Trichocyst: a cyst containing a defensive bristle in the ectosarc of Infusoria.
Trivium: the three rays of an echinoderm opposite to the bivium.
Trochanter: the segment of an insect's or a spider's leg, between the coxa and the femur.
Trochophore: a larval form common to polychætous annelids.
Tunic: the outer cuticular covering of tunicates.

Umbo: the protuberance above the hinge on the shell of a pelecypod.
Ureter: a tube forming the outlet of the kidney.
Uropod: the sixth swimmeret of the macruran decapod, that which forms the swimming tail.
Uterus: a dilated portion of the oviduct in which the egg or the developing animal is detained.

Vagina: the terminal division of the female reproductive tract.
Vas deferens: a duct leading from the testis toward the external opening, the sperm duct.
Vegetative organs: those organs which have to do with the processes of nutrition, growth, and the expulsion of wastes.
Vein: a vessel which brings blood toward the heart.
Velum: the circular muscular membrane of a medusa.
Ventral: on or toward the underside of an animal.
Ventricle: a chamber of the heart from which blood is sent over the body.
Viscera: the organs within the body cavities.
Visceral mass: the compact group of organs comprising the principal viscera in mollusks.

Wing-covers: the first pair of wings of a beetle.

Zoëa: a larval form of the crab and of certain other crustaceans.
Zoœcium: the outer cuticular covering of a bryozoan.

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